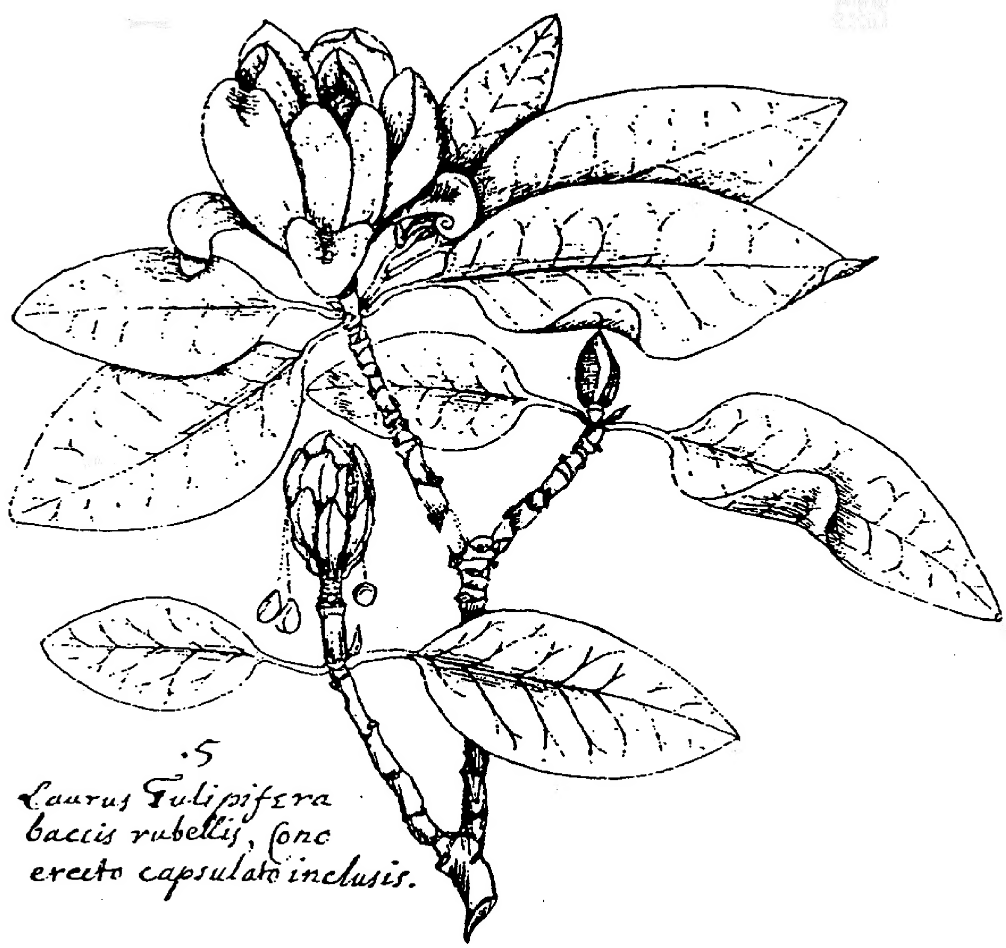
BANISTERIA

A JOURNAL DEVOTED TO THE NATURAL HISTORY OF VIRGINIA



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Cover: Sweetbay (*Magnolia virginiana*); original drawing by John Banister; sent to Bishop D. H. Compton in 1689.

Back cover: Calling males of American Toad (*Anaxyrus americanus*) and Spring Peeper (*Pseudacris crucifer*); photos by Steven M. Roble. See pages 34-46 of this issue for a paper on anuran vocalization patterns in northern Virginia.

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Banisteria, Number 39, pages 3-13

A Comparison of Lowland and Upland Forests of Fairy Stone State Park, Virginia. I. Vascular Plants

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ABSTRACT

Vascular plant community species composition and richness were measured in forests in lowland and upland topographic positions at Fairy Stone State Park, Patrick County, Virginia. Species richness was significantly higher in the lower (herbaceous plant level) and middle (shrub level) layers of lowland forests, but species richness in the upper (trees $\geq$10 cm diameter at breast height) layer did not differ between forest types. Upland forests tended to have higher stem density in the upper layer, but lower mean diameter-at-breast height. Tuliptree (*Liriodendron tulipifera*) was the most abundant species in the upper layer of lowland forests, while Sourwood (*Oxydendrum arboreum*) and oaks (*Quercus* spp.) were predominant in the upper layer of upland forests. Red Maple (*Acer rubrum*), White Oak (*Quercus alba*), and White Pine (*Pinus strobus*) were abundant in both forest topographic positions. Mountain Laurel (*Kalmia latifolia*), White Pine, and Red Maple were common species in the middle layer of both forest types, while American Beech (*Fagus grandifolia*) was also abundant in the middle layer of lowland forests. Japanese Stiltgrass (*Microstegium vimineum*), an invasive exotic species, was by far the most common species in the lower layer of lowland forests, while Blue Ridge Blueberry (*Vaccinium pallidum*) was the most common species in the lower layer of upland forests.

Key words: forest plant communities, biodiversity, topography, Blue Ridge Mountains.

INTRODUCTION

Numerous factors affect plant species composition in forests, including light availability, soil moisture, nutrients levels, temperature, and environmental disturbances. Many of these factors are linked to topographic variation, including slope position, aspect, and elevation (Desta et al., 2004). In the highly dissected terrain of the upper Piedmont and Blue Ridge physiographic provinces of Virginia, topographic factors play a major role in the structure of plant communities (Johnson & Ware, 1982; Stephenson, 1982; Farrell & Ware, 1988, 1991; Harrison et al., 1989; Copenheaver et al., 2006; Brown & Fredericksen, 2008), with subsequent impacts on animal communities. Topographic variation leads to differences in soil and air temperature, wind velocity, solar radiation, and humidity. In general, northern aspects, lower slope positions, and low slope inclinations are more mesic than southern aspects, upper slope positions, and steep slope inclinations (Rubino & McCarthy, 2003).

In 2010, we conducted a study comparing the vascular plant and vertebrate animal communities occurring on lowland topographic positions (toeslope and valley positions) and upland topographic positions (shoulder and ridgetop positions) in the forests of Fairy Stone State Park, Patrick County, Virginia. This paper describes the species richness, diversity, and composition, and relative stem density, of vascular plants in lowland and upland slope positions in the forests of the park. A companion paper describes the songbird and terrestrial vertebrate animal communities of these study sites.

STUDY SITE

Fairy Stone State Park is the largest of Virginia's six original state parks. The 1775-ha park in Patrick County is managed by the Virginia Department of

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Conservation and Recreation. Except for recreational areas that are heavily impacted by visitors, the park contains large areas of mature, undisturbed forest. Much of the park has highly dissected terrain with steep slopes and deep valleys characteristic of the foothills of the Blue Ridge Mountains.

In the latest Fairy Stone State Park management plan, one of the priorities is to conduct a biological inventory of the park in order to characterize its biodiversity, identify rare and endangered species, assess conservation threats, and recommend management actions. This information can help park staff manage access to areas that have rare species or species of special concern, as well as to identify areas threatened by invasive plant species.

METHODS

Experimental Design

A forest survey of the park conducted by the Virginia Department of Forestry in 1991 (W.R. Daniel & R.K. Clark, unpublished data) produced a map of forest types characterized by the most abundant species. We used this map to identify sampling areas in the park for two general forest types. The first type, hereafter referred to as "lowland forests", occupied lower slopes and streamsides. Common species include White Pine (*Pinus strobus*), Tuliptree (*Liriodendron tulipifera*), Northern Red Oak (*Quercus rubra*), and American Beech (*Fagus grandifolia*). The second forest type, hereafter referred to as "upland forests", includes species of upper slopes and ridges; common species present include Virginia Pine (*Pinus virginiana*), White Pine, Scarlet Oak (*Quercus coccinea*), and Chestnut Oak (*Quercus montana*). Using the map, as well as aerial photography and ground reconnaissance, we identified sites spread throughout the park with dissected terrain containing upland and lowland slope positions and which were not subjected to recent significant human disturbance (campgrounds, roads, heavily impacted trail areas, or other development). In these areas, we located ten pairs of sampling plots (upland and lowland) at a set distance from an opportunistically located starting position (typically a landmark, such as a trail junction, sign, or boundary marker).

Sampling

Plots were nested to sample different forest strata: upper (composed of overstory and midstory trees $\geq$10 cm dbh), middle (shrubs, vines and trees $\geq$1 m tall, but <10 cm dbh), and lower (herbaceous plants and seedlings of woody plants <1 m tall). Plots for the upper layer were 20 x 50 m in size. Within this plot, all live trees $\geq$10 cm dbh were identified to species and their dbh was measured. Through the center of this plot lengthwise, a 4 x 50 m belt transect for the middle layer was established where all trees, shrubs, and vines >1 m tall, but <10 cm dbh, that were rooted in the plot were counted by species. For the lower layer (plants $\leq$1 m tall), ten 1 x 1 m plots were established along the centerline of the main plot at 5 m intervals. Plants in these plots were counted and identified to species, or genus level if they could not be identified to species. A search of the entire 20 x 50 m main plot was also conducted for any species in any sample layer not included within measured plots to determine overall species richness. Sampling was carried out from June to August 2010. Plant taxonomy followed Wofford (1989).

Data Analysis

The upper layer plot (20 x 50 m) was used as the experimental unit for all data analyses (n=10). Species richness was calculated at the tree layer plot level for the three layers. Stem density was determined for each species in each of the three layer plots. Paired t tests were used for statistical comparisons of species richness and stem density for upland and lowland plots using SYSTAT 12.2 (SYSTAT Software Inc., San Jose, CA). In addition, species composition differences in the upper layer among all plots were explored with detrended correspondence analysis (DCA) using PC-ORD 5 (MJM software, Gleneden Beach, OR).

RESULTS

Plant species richness in the lower layer of lowland forest plots was nearly double that of upland plots ($t = 5.79$, $p < 0.001$; Fig. 1). Middle layer species richness also was significantly higher in lowland compared to upland plots ($t = 2.75$, $p = 0.02$; Fig. 1). Upper layer species richness was similar between upland and lowland plots ($t = 0.26$, $p = 0.80$; Fig. 1).

In the upper layer, upland forests had more trees in the smaller diameter classes than lowland forests, whereas lowland forests had a higher density of large trees (Fig. 2). The median DBH of all trees was higher in lowland plots (22.5 cm) than upland plots (20.0 cm). The mean number of trees per plot was higher in upland forests ($t = 3.24$, $p = 0.01$, Table 1).

Tuliptree was, by far, the most abundant species in the lowland plots, often occurring as a canopy tree species (Table 1). An understory tree, Sourwood (*Oxydendrum arboreum*), was the most abundant tree

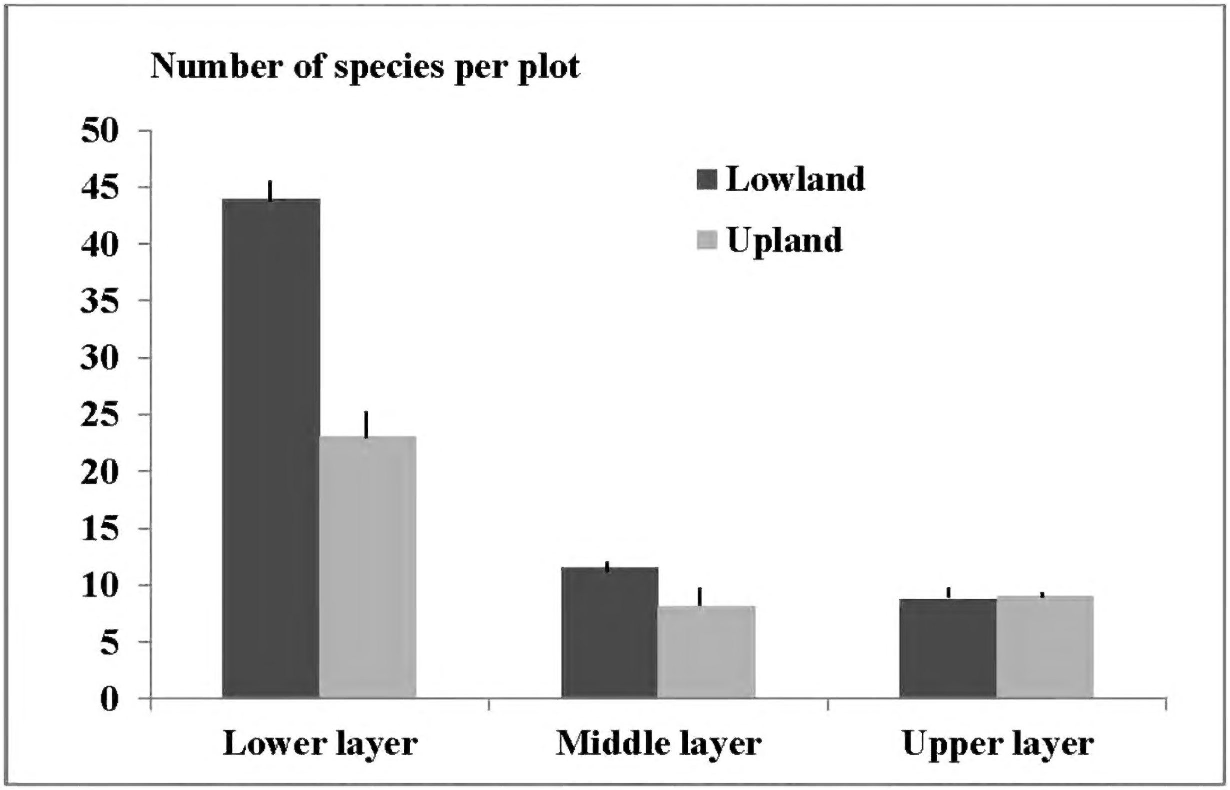

Fig. 1. Mean (+ standard error) species richness of plants in the lower layer (<1 m tall), middle layer (>1 m tall but <10 cm DBH), and upper layer (≥10 cm DBH) in lowland and upland forests at Fairy Stone State Park, Patrick County, Virginia.

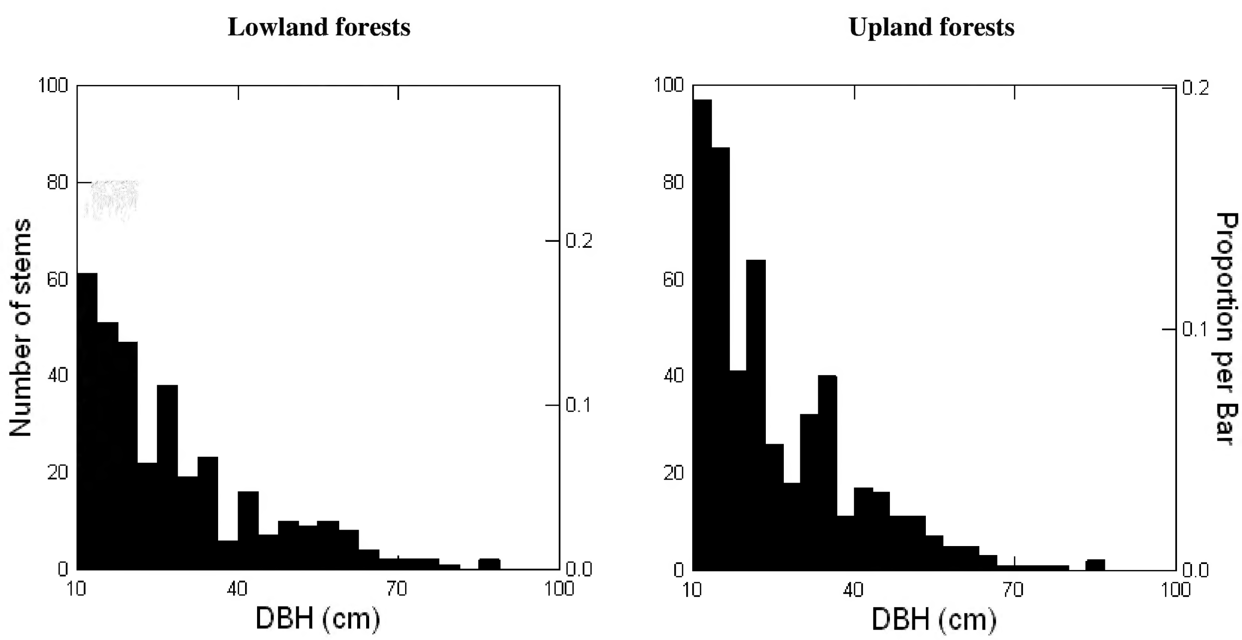

Fig. 2. Diameter distribution of trees ≥10 cm (dbh) in lowland and upland forests of Fairy Stone State Park, Virginia.

Table 1. Mean number of stems/ha for species in the upper layer (≥10 cm DBH) in lowland and upland forests of Fairy Stone State Park, Virginia.

Lowland forests		**Upland forests**	
Species	**#/ha**	**Species**	**#/ha**
Liriodendron tulipifera	88	*Oxydendrum arboreum*	89
Acer rubrum	42	*Acer rubrum*	68
Quercus alba	37	*Quercus montana*	65
Oxydendrum arboreum	28	*Quercus alba*	65
Pinus strobus	27	*Pinus strobus*	63
Fagus grandifolia	19	*Liriodendron tulipifera*	33
Betula lenta	17	*Quercus coccinea*	33
Nyssa sylvatica	12	*Nyssa sylvatica*	19
Cornus florida	12	*Quercus velutina*	12
Carya glabra	9	*Carya glabra*	11
Quercus rubra	8	*Carya tomentosa*	10
Carpinus caroliniana	7	*Pinus echinata*	9
Cercis canadensis	7	*Pinus virginiana*	6
Juglans nigra	6	*Pinus rigida*	5
Fraxinus pennsylvanica	6	*Quercus falcata*	3
Carya tomentosa	6	*Fagus grandifolia*	3
Platanus occidentalis	3	*Cornus florida*	2
Magnolia fraseri	2	*Quercus rubra*	1
Sassafras albidum	1	*Magnolia acuminata*	1
Quercus velutina	1	*Betula lenta*	1
Quercus montana	1		
Pinus virginiana	1		
TOTAL	**340**		**499**

species in upland plots, but was also one of the most common species in lowland plots, although it had only about one-third of the stem density as in upland plots (Table 1). Oaks were much more common in upland plots, with a particularly higher abundance of Chestnut Oak and Scarlet Oak. White Oak (*Quercus alba*), was among the most common species in both forest types, although it was approximately twice as abundant in upland plots. Red Maple (*Acer rubrum*) and White Pine were also among the most common species in both forest types, although they had higher stem densities in the upland plots. Species occurring with higher densities in lowland plots included American Beech and Black Birch (*Betula lenta*). Other species occurred only in lowland plots, although at low densities, including American Hornbeam (*Carpinus caroliniana*), Eastern Redbud (*Cercis canadensis*), Green Ash (*Fraxinus pennsylvanica*), American Sycamore (*Platanus occidentalis*), Fraser Magnolia (*Magnolia fraseri*), and Sassafras (*Sassafras albidum*). Two pine species, Shortleaf Pine (*Pinus echinata*) and Pitch Pine (*P. rigida*), only occurred on upland plots. Hickories (*Carya* spp.) occurred with similar abundance in upland and lowland plots.

Detrended correspondence analysis (DCA) of the upper layer data indicated a clear separation between lowland and upland plots along the first axis (Fig. 3), which explained approximately 44% of the variation in the data. Species on the right side of DCA Axis 1 occurred commonly in lowland plots, but not in upland plots. Species that were more abundant in upland plots occurred on the left side of the first axis. DCA Axis 2 explained only 19% of the variation in the data and it was less clear what factors were associated with this axis. One upland plot (plot 18) was isolated from other upland plots on one end of this axis (Fig. 3). This plot was on a ridgetop/south-facing shoulder position and had a high abundance of Scarlet Oak, Shortleaf Pine, and Pitch Pine. For lowland plots, this axis separated American Beech, Green Ash, American Sycamore, and Black Walnut (*Juglans nigra*) from species such as Flowering Dogwood, American Redbud, Black Birch, and American Hornbeam (Fig. 3). Species with intermediate positions relative to these two axes included tree species such as White Pine, Red Maple, and White Oak (Fig. 3) that have wide environmental tolerance. Northern Red Oak also appeared as an intermediate species, presumably because it occurred on upland plots with north-facing slopes and also in lowland plots on toeslope positions.

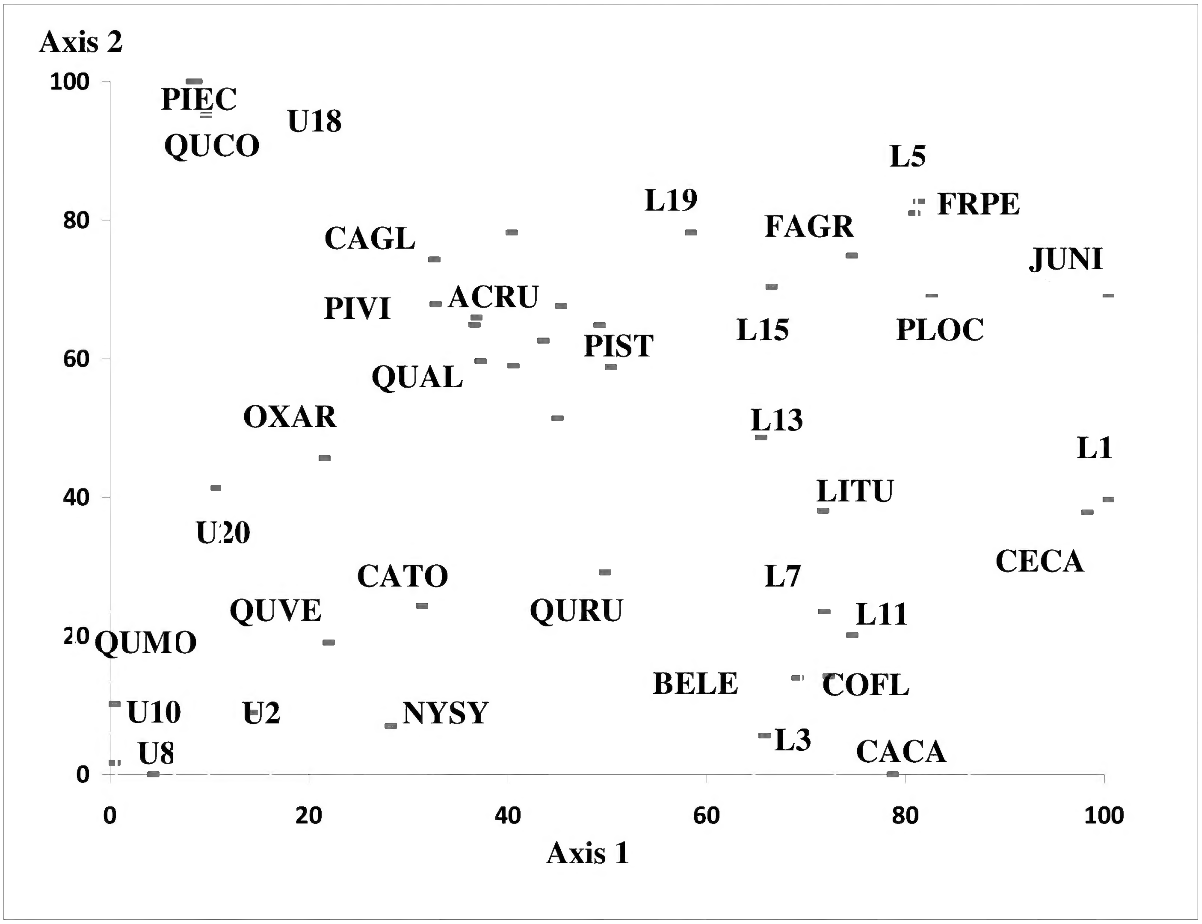

Fig. 3. Detrended correspondence analysis of tree species ≥10 cm dbh and sampling scores along the first and second axes of the ordination. Species codes: ACRU=*Acer rubrum*, BELE=*Betula lenta*, CACA=*Carpinus caroliniana*, CAGL=*Carya glabra*, CATO=*Carya tomentosa*, CECA=*Cercis canadensis*, COFL=*Cornus florida*, FAGR=*Fagus grandifolia*, FRPE=*Fraxinus pennsylvanica*, JUNI=*Juglans nigra*, LITU=*Liriodendron tulipifera*, OXAR=*Oxydendrum arboreum*, NYSY=*Nyssa sylvatica*, PLOC=*Platanus occidentalis*, QUAL=*Quercus alba*, QUCO=*Quercus coccinea*, QUMO=*Quercus montana*, QURU=*Quercus rubra*, QUVE=*Quercus velutina*, PIEC=*Pinus echinata*, PIST=*Pinus strobus*, PIVI=*Pinus virginiana*. Upland and lowland plot scores are noted as "U" and "L" along with the plot number.

Middle layer density did not differ between lowland and upland plots (t = 0.11, p = 0.92; Table 2). American Beech was the most abundant middle layer species in lowland forest plots, but was relatively rare in upland plots. Mountain Laurel (*Kalmia latifolia*) was the most abundant species in this layer in upland plots, and it was also abundant in lowland plots. White Pine and Red Maple were among the most abundant middle layer species for both topographic positions. Species with relatively high abundance in lowland plots, but which did not occur or rarely occurred in the middle layer of upland plots, included American Hornbeam, Great Laurel (*Rhododendron maximum*), and Green Ash. Sourwood, Chestnut Oak, and Blackgum (*Nyssa sylvatica*) had much higher abundances in the middle layer of upland compared to lowland plots.

Lower layer plant density was significantly higher in lowland plots (t = 2.69, p = 0.025; Table 3). By far, the most abundant species in the lower layer of lowland plots was Japanese Stiltgrass (*Microstegium vimineum*), an invasive exotic species commonly occurring in mesic habitats (Table 3). Also abundant in lowland plots were Hay-scented Fern (*Dennstaedtia punctilobula*) and seedlings of Green Ash. The most abundant species in upland plots was Blue Ridge Blueberry (*Vaccinium pallidum*) (Table 3). Seedlings of Red Maple, White Pine, and Mountain Laurel were abundant in both forest types. Seedlings of Black Birch (*Betula lenta*) and Tuliptree were abundant on lowland plots.

Table 2. Mean number of stems/ha for species in the middle layer (<10 cm DBH, but ≥1 m in height) in lowland and upland forests of Fairy Stone State Park, Virginia.

Lowland forests		Upland forests	
Species	**#/ha**	**Species**	**#/ha**
Fagus grandifolia	540	*Kalmia latifolia*	710
Kalmia latifolia	450	*Pinus strobus*	565
Pinus strobus	370	*Acer rubrum*	440
Carpinus caroliniana	180	*Oxydendrum arboreum*	150
Acer rubrum	140	*Quercus montana*	90
Rhododendron maximum	125	*Nyssa sylvatica*	85
Cornus florida	65	*Cornus florida*	35
Fraxinus pennsylvanica	50	*Fagus grandifolia*	20
Oxydendrum arboreum	45	*Ilex opaca*	20
Ilex opaca	35	*Quercus alba*	20
Magnolia fraseri	20	*Magnolia acuminata*	15
Quercus montana	20	*Carya glabra*	10
Hamamelis virginiana	15	*Betula lenta*	10
Cercis canadensis	15	*Cercis canadensis*	10
Acer saccharum	10	*Quercus coccinea*	10
Betula lenta	10	*Quercus rubra*	5
Quercus velutina	10	*Quercus velutina*	5
Carya cordiformis	10	*Castanea dentata*	5
Lindera benzoin	10	*Vaccinium corymbosum*	5
Nyssa sylvatica	10	*Carya tomentosa*	5
Carya glabra	10	*Carpinus caroliniana*	5
Vaccinium stamineum	5	*Acer saccharum*	5
Carya tomentosa	5		
TOTAL	**2150**	**TOTAL**	**2225**

Table 3. Mean number of stems/m^2 for species in the lower layer (<1 m tall) in lowland and upland forests of Fairy Stone State Park, Virginia.

Lowland forests		Upland forests	
Species	**#/m^2**	**Species**	**#/m^2**
Microstegium vimineum	4.73	*Vaccinium pallidum*	0.84
Fraxinus pennslyvanica	1.61	*Acer rubrum*	0.77
Dennstaedtia punctilobula	1.58	*Smilax* spp.	0.67
Potentilla canadensis	1.30	*Pinus strobus*	0.35
Viola spp.	1.16	*Kalmia latifolia*	0.32
Betula lenta	1.00	*Galax urceolata*	0.25
Acer rubrum	0.79	*Quercus montana*	0.24
Liriodendron tulipifera	0.68	*Quercus velutina*	0.18
Smilax spp.	0.67	*Chimaphila maculata*	0.15
Kalmia latifolia	0.50	*Quercus alba*	0.11
Galium spp.	0.42	*Viola* spp.	0.08
Pinus strobus	0.39	*Galium* spp.	0.08
Hepatica americana	0.35	*Carex* spp.	0.08
Ranunculus spp.	0.34	Others	0.95
Mitchella repens	0.28		
Cercis canadensis	0.25		
Euonymus americanus	0.24		
Galax urceolata	0.19		
Fagus grandifolia	0.19		
Anemone quinquefolia	0.17		
Chimaphila maculata	0.15		
Polystichum acrostichoides	0.15		
Others	2.10		
TOTAL	**19.5**	**TOTAL**	**5.5**

DISCUSSION

The higher lower and middle layer species richness of lowland compared to upland plots may be due to higher moisture conditions on these sites. Other studies have found greater understory plant richness and cover on more mesic slope positions (Heubner et al., 1995; Hutchinson et al., 1999; Small & McCarthy, 2005). On drier, upland sites, moisture and nutrient limitations may restrict plant cover and species richness. The higher species richness on lowlands was somewhat compromised, however, by the high relative abundance of Japanese Stiltgrass. This species commonly invades mesic sites and is spread through seed dispersal by streams and rivers (Barden, 1987). While the middle layer of lowland plots had a higher average number of species per plot, total middle layer species richness of lowland and upland plots differed by only one species. Gilliam (2007) noted that species-rich herb layers generally occur in areas with species-rich overstories. Mean tree layer species richness did not differ, however, between lowland and upland plots, although there were four more tree species on lowland sites when summed over all plots.

Structural differences in tree density and diameter distribution were observed between upland and lowland plots, with a higher density on upland plots and a larger mean diameter on lowland plots. This pattern was also observed in studies by Desta et al. (2004) and Brown & Fredericksen (2008). Desta et al. (2004) noted that tree density may be higher on more xeric sites due to a more open canopy, as well as a slower process of competitive exclusion of stems compared to lowland sites. The better growing conditions and lower density on lowland sites may also contribute to larger stem diameters.

It is interesting to note that both topographic positions shared five of the six most common upper layer species, including Tuliptree, Red Maple, White Oak, White Pine, and Sourwood. However, the mean density and abundance rank of these species differed dramatically. For example, there was an almost inverse shift in the density and abundance rank of Tuliptree (the most abundant species on lowland plots) and Sourwood (the most abundant species on upland plots). Red Maple, White Oak, and White Pine are largely considered to be generalist species (Abrams, 1998, Elliott et al., 1999). These species also occurred in the center of the DCA ordination, suggesting that they are generalists along the spectrum of species sampled in this study. Elliott et al. (1999) also considered Sourwood, Chestnut Oak, and Blackgum to be habitat generalists in the southern Appalachians, but these species were much more abundant on upland sites in our study. Brown & Fredericksen (2008) also found these species to be associated with sideslope and shoulder positions on a study site in Franklin County, Virginia. There was a clear separation in the DCA ordination between species occurring on drier upper slopes (ridgetops and south-facing upper slopes), which had high abundances of Scarlet Oak, Shortleaf Pine, and Pitch Pine, and other upper slope positions which contained more Chestnut Oak, Black Oak, Blackgum, and Mockernut Hickory. While Tuliptree was much more abundant on lowland sites (Harrison et al., 1989; Elliott et al., 1999; Brown & Fredericksen, 2008), it was somewhat surprising to see this species rank so high in abundance on upland sites, although plots located on north- and east-facing upper slopes provide the mesic habitat conditions required by this species.

The upland forests in the Blue Ridge Mountains of Virginia were once dominated by American Chestnut (*Castanea dentata*) until the invasion of the Chestnut Blight fungus (*Endothia parasitica*) in the 1920s (Johnson & Ware, 1982). Sprouts of American Chestnut were occasionally found in the sample plots of this study. Following the loss of Chestnut, highest rankings of density and basal area in upland forests have been shared by a number of tree species, predominantly oaks and hickories (Johnson & Ware, 1982). While oak species were more abundant in upland plots, hickories had a similar abundance in upland and lowland plots.

Except for a large ice storm in 1994, the forests of Fairy Stone State Park have been largely undisturbed, as evidenced by large-diameter trees and closed-canopy forests. An abundance of White-tailed Deer (*Odocoileus virginianus*) in the park may have impacted forest understory plant abundance and species composition because there was evidence of browsing in many sample plots. The abundance of Tuliptree, particularly on lowland plots in this study, is probably a legacy of high recruitment on sites following the abandonment of cultivation. The species is a long-lived pioneer adapted to germination on scarified soil and rapid growth under full sunlight (Beck, 1990). The shaded understory of both upland and lowland plots, along with dense low shade created by Mountain Laurel (primarily on upland sites) and Rhododendron (primarily on lowland sites), may inhibit recruitment of Tuliptree into the middle layer.

In the continued absence of disturbance, it appears that the species composition in the upland plots in the park will shift towards a higher abundance of Red Maple and White Pine, as evidenced by the abundance of these species in the middle and lower layers. Red Maple, in particular, has been observed to have high recruitment and increasing abundance in the understories of oak forests in the eastern U.S. (Lorimer,

1984; Abrams & Downs, 1990; McEwan et al., 2005). While there were some plots with oak regeneration in the lower layer, advancement to the middle layer appears to be limited. White Pine was abundant in all layers of both upland and lowland forests, although it tended to be more abundant in the upper and middle layer of upland forests. Copenheaver et al. (2006) found that White Pine had higher recruitment on younger, mid-slope stands on a site in the Ridge and Valley Province of Virginia. The successful recruitment of White Pine into the middle layer at Fairy Stone State Park may be a result of the 1994 ice storms that probably created a more open canopy through damage to overstory tree crowns.

As with upland plots, shifts in species composition on lowland plots also seem likely in the future, changing from current dominance by Tuliptree, which shows limited recruitment in the understory, towards American Beech, White Pine, and Red Maple. This pattern, observed in both lowland and upland plots, lends support to the "mesophication" hypothesis of eastern hardwood forests (Nowacki & Abrams, 2008), with species adapted to mesic sites increasing at the expense of oaks and other xeric species. This trend in mesophication is largely attributed to fire exclusion (Nowicki & Abrams, 2008; Martin et al., 2011).

In lowland forests, Black Birch and Green Ash also had abundant seedling regeneration, but there does not appear to be much success for these species in recruitment to the middle layer. The high density of Japanese Stiltgrass in lowland forest plots is also likely to negatively affect the establishment of tree species in these forests, as well as decrease plant diversity. Few other exotic species were found in plots during this study because they were located in interior forests where it is difficult for invasive species to become established (Gilliam, 2007). We observed patches of invasive exotic species, however, in other areas of the park along edges and disturbed areas including Tree-of-heaven (*Ailanthus altissima*), Japanese Honeysuckle (*Lonicera japonica*), Chinese Privet (*Ligustrum sinensis*), Periwinkle (*Vinca minor*), Wisteria (*Wisteria sinensis*), Autumn Olive (*Elaeagnus umbellata*), and Princess Tree (*Paulownia tomentosa*).

While there were some clear differences in species richness and composition in this study between upland and lowland forests, considerable extraneous variation can make interpretation of these data difficult. First, there were too few sample plots in the study to quantitatively determine the influence of aspect and slope angle on these plant communities. In addition, the variations in microtopography among lower slope and upland sites, along with associated microclimatic elements, could have led to additional unexplained variation in the data. These factors, along with the interrelationship between topography and land use history, can make it difficult to determine the full extent of the influence of topography on plant communities (Harrison et al., 1989).

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Appendix 1. GPS coordinates of sampling plots in decimal degrees. Asterisks indicate permanent sampling plots for trees >10 cm dbh.

Plot number	Topographic position	Coordinates	Location description
1*	Lowland	36.79796, -80.11835	Southwest of Stuart's Knob parking area
2*	Upland	36.79780, -80.12000	Uphill from plot 1, 100 m North of beach overlook
3*	Lowland	36.78835, -80.11546	Valley behind water treatment pond across from picnic area
4*	Upland	36.79938, -80.11621	50 m South of maintenance storage area
5*	Lowland	36.80567, -80.11215	Road to dam on right just after first curve to left
6*	Upland	36.80610, -80.11318	On shoulder ridge West of plot 5
7*	Lowland	36.77776, -80.10036	In cove, South from paved trail, 150 m from Goose Point Road
8*	Upland	36.77896, -80.09739	North of paved trail, 50 m from Goose Point Road
9	Lowland	36.78299, -80.09719	Little Mountain Falls Trail North of Plot 10 on right side past first creek
10	Upland	36.78117, -80.10040	Little Mountain Falls Trail on left just past half-way point marker
11	Lowland	36.79286, -80.11106	Oak-hickory Trail near roads and trails interpretative sign
12	Upland	36.78973, -80.11251	Oak-hickory Trail, 200 m South of trailhead
13	Lowland	36.79573, -80.10659	Lakeshore Trail, along ephemeral stream near pavilion
14	Upland	36.79722, -80.10496	100 uphill from junction of Lakeshore and Turkey Ridge Trail
15	Lowland	36.78519, -80.11249	Crossover Trail on right 250 m from Little Mountain Falls Trail
16	Upland	36.78760, -80.11688	Little Mountain Falls Trail on right 200 m from juncture with Crossover Trail
17	Lowland	36.77250, -80.10625	North of State Road 57, along stream West of Plot 18
18	Upland	36.77109, -80.10401	North of State Road 57, near sign for Rt. 822
19	Lowland	36.81448, -80.11343	Fairy Stone Park Road, left side 150 m South of Park Boundary Road Gate
20	Upland	36.81538, -80.11236	Park Boundary Road off Fairy Stone Park Road – 150 m on right

Appendix 2. List of additional rarely encountered species occurring within sampling plots, but not listed in Tables 1-3.

Lowland forests

Adiantum pedatum
Ailanthus altissima
Agrimonia spp.
Ambrosia artemisiifolia
Amelanchier arborea
Arisaema triphyllum
Asimina triloba
Asplenium montanum
Botrychium dissectum
Carex spp.
Chrysogonum virginianum
Castanea dentata
Claytonia virginica
Crataegus spp.
Cymophyllus fraseri
Cynoglossum virginianum
Cyperus spp.
Dentaria lacinata
Desmodium spp.
Dioscorea villosa
Diospyros virginiana
Dryopteris spp.
Elaeagnus umbellata
Galax urceolata
Geranium maculatum
Goodyera pubescens
Hepatica acutiloba
Hexastylis virginica
Hieracium venosum
Houstonia caerulea
Iris cristata
Juniperus virginiana
Ligustrum sinense
Lonicera japonica
Lycopodium lucidulum
Magnolia acuminata
Magnolia tripetala
Medeola virginiana
Menispermum candense
Monotropa uniflora
Orchis spectabilis
Osmunda cinnamomea
Oxalis stricta
Panicum spp.
Parthenocissus quinquefolia
Pinus echinata
Podophyllum peltatum
Prenanthes serpentaria
Rhododendron calendulaceum
Rhus radicans
Rhynchospora capitellata
Rubus spp.
Sanguinaria canadensis
Silene virginica
Smilacina racemosa
Solidago spp.
Symplocarpus foetidus
Thalictrum thalictroides
Tiarella cordifolia
Trifolium spp.
Trillium grandiflorum
Urtica dioica
Uvularia perfoliata
Uvularia sessilifolia
Verbesena alternifolia
Viburnum acerifolium
Viburnum prunifolium
Vinca minor
Vitus labrusca

Upland forests

Ailanthus altissima
Amelanchier arborea
Antennaria spp.
Asplenium spp.
Castanea dentata
Conopholis americana
Cynoglossum virginianum
Desmodium spp.
Dioscorea villosa
Diospyros virginiana
Euonymus americana
Fraxinus americana
Goodyera pubescens
Hamamelis virginiana
Hexastylis virginica
Hieracium venosum
Hypericum hypericoides
Juniperus virginiana
Medeola virginiana
Microstegium virmineum
Monotropa uniflora
Oxalis stricta
Panicum spp.
Parthenocissus quinquefolia
Polypodium virginianum
Polystichum acrostichoides
Potentilla canadensis
Prenanthes serpentaria
Prunus serotina
Ranunculus spp.
Rhododendron nudiflorum
Rhus radicans
Rhynchospora capitellata
Robinia pseudoacacia
Rubus spp.
Sassafras albidum
Tiarella cordifolia
Thalictrum thalictroides
Uvularia sessilifolia
Viburnum acerifolium
Vitus labrusca

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A Comparison of Lowland and Upland Forests of Fairy Stone State Park, Virginia. II. Small Terrestrial Vertebrates and Songbirds

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ABSTRACT

Small terrestrial vertebrate and songbird abundance, species richness, and species composition were studied in forests in both lowland and upland topographic positions at Fairy Stone State Park, Patrick County, Virginia. Songbird species were sampled using point counts and herpetofauna and small mammals were sampled using live traps. The species richness and abundance of songbirds did not differ markedly between upland and lowland forest plots, although there were some changes in species composition. Small mammal and reptile communities were similar in species richness, abundance, and composition between upland and lowland forests. Amphibian species were observed in higher abundance on upland sites, mostly due to a large number of captures of juvenile American Toads. These toads, however, emerged from water sources on lowland sites. Nearly all frogs were on lowland sites and we had incidental observations of four stream salamanders at lowland sites.

Key words: Blue Ridge Mountains, topography, wildlife, forest vertebrate diversity.

INTRODUCTION

In the Upper Piedmont and Blue Ridge physiographic provinces of Virginia, topographic factors play an important role in structuring forest plant communities (Johnson & Ware, 1982; Stephenson, 1982; Farrell & Ware, 1988, 1991; Harrison et al., 1989; Copenheaver et al., 2006; Brown & Fredericksen, 2008). Because plant communities influence food, cover, and nesting locations of animals, animal communities may also differ by topographic position, at least for species with relatively small home ranges. Topographic variation leads to differences in soil and air temperature, wind velocity, solar radiation, and humidity. In general, northern aspects, lower slope positions, and low slope inclinations are more mesic than southern aspects, upper slope positions, and steep slope inclinations (Rubino & McCarthy, 2003). Species dependent on sites with higher soil moisture and humidity, such as amphibians, may therefore be abundant in forests on lower slope positions compared to upper slope positions. In addition, food and cover for animals may differ between upland and lowland forests. For example, upland oak forests may provide more mast for small mammal communities (Rodewald, 2003), while lowland forests may provide more understory cover for wildlife than upland forests (Small & McCarthy, 2005).

In 2010, we conducted a study comparing the vascular plant and terrestrial vertebrate communities on lowland (toeslope and valley positions) and upland (shoulder and ridgetop positions) topographic positions in the forests of Fairy Stone State Park, Patrick County, Virginia. This paper describes the species richness, abundance, and composition of small terrestrial vertebrates and songbirds in lowland and upland locations in the forests of the park. A companion paper describes the vascular plant communities on these study sites.

STUDY SITE

Fairy Stone State Park is the largest of Virginia's six original state parks. The 1775-ha park in Patrick County is managed by the Virginia Department of Conservation and Recreation. Except for recreational

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areas that are heavily used by visitors, the park contains large areas of mature, undisturbed forest. Much of the park is highly dissected with steep slopes and deep valleys characteristic of the foothills of the Blue Ridge Mountains.

In the latest Fairy Stone State Park management plan, one of the priorities is to conduct a biological inventory of the park in order to characterize its biodiversity, identify rare and endangered species, assess conservation threats, and recommend management actions. This information can help park staff manage access to areas that have rare species or species of special concern, as well as to identify areas threatened by invasive plant species.

METHODS

Experimental Design

Lowland and upland forest types were located throughout the park using methods described in the companion paper. The first type, hereafter referred to as "lowland forests", occupied lower slopes and streamside forests. Dominant canopy species include Tuliptree (*Liriodendron tulipifera*) and American Beech *(Fagus grandifolia*). The second forest type, hereafter referred to as "upland forests", includes species of upper slopes and ridges where dominant canopy species include Scarlet Oak (*Quercus coccinea*) and Chestnut Oak (*Quercus montana*). White Pine (*Pinus strobus*), White Oak (*Quercus alba*), and Red Maple (*Acer rubrum*) are common on both upland and lowland sites. As described below, sampling methods differed according to the taxa of terrestrial vertebrate animals being studied (birds, small mammals, herpetofauna).

Point Counts

Songbirds were sampled using point counts along established trails within the park, including a total of 30 points. Each point had a sampling area of 50 m in radius and the outer margin of the sampling area was at least 150 m from roads and at least 100 m from other sampling areas. From late-April to mid-June, each point was sampled four times, thus including sampling of breeding birds and some migrants. On sampling days, 10 points were sampled per day from 0600-0900 hours with approximately half of each in lowland forests and the remainder in upland forests. Four of the 30 points had some overlap between upland and lowland forest characteristics (e.g., steep ravines with upland tree species on either side) and were thus considered to be "transitional" between forest types. Of the remaining 26 point sampling areas, 14 were entirely in lowland topographic positions (valley and toeslope positions) and 12 were entirely in upland topographic positions (ridgetop and shoulder positions). For each point, all songbirds seen or heard within the point count area over a time interval of five minutes were tallied.

Pitfall Trapping

Three pairs of drift fence-pitfall arrays were established in the park (one each in the northwestern, central, and southeastern sections) to sample small mammals, amphibians, and reptiles. Each pair included lowland and upland topographic positions along the same slope, separated by at least 100 m. Two of three lowland pitfall arrays were located adjacent to small streams. Each array included 5 m arms of silt fencing in the form of an X with five 17-l buckets (one in the center and one at the end of each arm) buried so their tops were flush with the soil surface. The traps at each site were opened most weekdays from mid-March to mid-August for a total of 420 trap-nights (5 buckets x 84 days) per array (n=3) and 1260 trap-nights per treatment. Traps were checked in the morning of each day and captured animals were identified to species and released unmarked just outside of and facing away from the sampling area.

Live Trapping

Small mammals were sampled from June-August using Sherman live traps in four pairs of upland and lowland sites located in different areas of the park. At each site, a total of 30 traps were set with ten trapping locations separated by 50 m. At each trapping location, three traps were placed in a triangular pattern 10 m apart. Traps were baited with a mixture of peanut butter, oats, and sunflower seeds. Each of the four paired locations was trapped over an eight-day period for a total of 960 trap-nights per upland or lowland forest type (30 traps x 8 nights x 4 locations). Captured animals were ear-tagged and released, except for shrews which were not ear-tagged. We also set out two Tomahawk traps baited with sardines and marshmallows along each trap line to reduce the incidence of trap disturbance by Raccoons (*Procyon lotor*) and Virginia Opossums (*Didelphis virginiana*).

Data Analysis

Songbird abundance per point was averaged over the four sampling periods per point and a Kruskal-Wallis test examined differences in abundance among upland, lowland, and transitional areas. Paired t tests or

Wilcoxon signed rank tests were used for statistical comparisons of mammal and herpetofauna abundance between upland and lowland pitfall arrays and Sherman trap locations. Differences in species richness were not tested statistically due to relatively low species counts per replicate for point counts and trapping locations. All analyses were conducted using SYSTAT 12.2 (SYSTAT Software Inc., San Jose, CA). Due to low numbers of replicates for many species groups and individual species, differences were considered significant at $p < 0.10$.

RESULTS

The abundance of birds estimated from point counts did not differ among upland, lowland, and transitional forests ($p = 0.13$), but there was a tendency for a higher abundance of birds at lowland and transitional sites (Table 1). The species richness summed over all points only differed by three species between upland and lowland sites. Red-eyed Vireo (*Vireo olivaceus*) was the most abundant bird on all forest types and its abundance was similar between upland and lowland sites (Table 1). Ovenbird (*Seiurus aurocapillus*) was also a commonly observed species with similar abundances on upland and lowland sites. Tufted Titmouse (*Baeolophus bicolor*) was another commonly observed species in both upland and lowland forests, but it had >50% higher abundance on lowland sites. Blue-headed Vireo (*Vireo solitarius*), Yellow-throated Vireo (*Vireo flavifrons*), and Hairy Woodpecker (*Picoides villosus*) tended to occur in higher abundance on upland sites and Great-crested Flycatcher (*Myiarchus crinitus*) and Black-and-white Warbler (*Mniotilta varia*) were observed more than once during sampling on upland sites, but neither was recorded on lowland sites. On lowland sites, Acadian Flycatcher (*Empidonax virescens*) and Wood Thrush (*Hylocichla mustelina*) were relatively common, but they were absent on upland sites, as were the less common Louisiana Waterthrush (*Seiurus motacilla*) and American Redstart (*Setophaga ruticilla*).

Table 1. Mean number of birds detected per point in upland, lowland, and transitional topographic positions in forests of Fairy Stone State Park, Patrick County, Virginia. The number of points is given as the sample size. Each point was sampled four times between late April and mid-June, 2010. Summed over all species, the number of birds per point did not differ by topographic position ($p = 0.13$, Kruskal-Wallis test).

Lowland (n=14)	#	Upland (n=12)	#	Transitional (n=4)	#
Vireo olivaceus	0.39	*Vireo olivaceus*	0.38	*Vireo olivaceus*	0.56
Baeolophus bicolor	0.32	*Seiurus aurocapillus*	0.21	*Empidonax virescens*	0.38
Empidonax virescens	0.27	*Baeolophus bicolor*	0.19	*Piranga olivacea*	0.31
Seiurus aurocapillus	0.25	*Vireo solitarius*	0.17	*Vireo flavifrons*	0.25
Piranga olivacea	0.14	*Vireo flavifrons*	0.10	*Vireo solitarius*	0.19
Hylocichla mustelina	0.13	*Picoides villosus*	0.10	*Seiurus aurocapillus*	0.13
Vireo solitarius	0.05	*Piranga olivacea*	0.08	*Helmitheros vermivorus*	0.06
Sitta carolinensis	0.05	*Myiarchus crinitus*	0.06	*Cyanocitta cristata*	0.06
Thryothorus ludovicianus	0.05	*Melanerpes carolinus*	0.04	*Wilsonia citrina*	0.06
Melanerpes carolinus	0.04	*Mniotilta varia*	0.04	*Seiurus noveboracensis*	0.06
Seiurus motacilla	0.04	*Wilsonia citrina*	0.02	*Picoides villosus*	0.06
Vireo flavifrons	0.04	*Empidonax virescens*	0.02	*Cardinalis cardinalis*	0.06
Setophaga ruticilla	0.04	*Sitta carolinensis*	0.02	*Baeolophus bicolor*	0.06
Picoides villosus	0.04	*Archilochus colubris*	0.02	Unidentified	0.06
Poecile carolinensis	0.02	*Catharus ustulatus*	0.02		
Cardinalis cardinalis	0.02	*Dendroica virens*	0.02		
Cyanocitta cristata	0.02	*Poecile carolinensis*	0.02		
Unidentified	0.17	*Cardinalis cardinalis*	0.02		
		Coccyzus americanus	0.02		
		Dendroica pinus	0.02		
		Contopus virens	0.02		
		Unidentified	0.08		
TOTAL	**2.08**	**TOTAL**	**1.67**	**TOTAL**	**2.30**

Table 2. Number of small mammals captured in pitfall arrays in lowland and upland forests of Fairy Stone State Park, Patrick County, Virginia.

Species	Lowland	Upland
Peromyscus leucopus	7	9
Myodes gapperi	5	4
Ochrotomys nuttalli	0	1
Napaeozapus insignis	1	1
Blarina brevicauda	9	4
Sorex cinereus	3	10
Sorex fumeus	8	12
TOTAL	**33**	**41**

There was no difference in the number of small mammal captures in Sherman traps (not including recaptures) between lowland and upland plots (p = 0.72). White-footed Mouse (*Peromyscus leucopus*) comprised the majority of captures (33 in upland and 37 in lowland forests). Two Short-tailed Shrews (*Blarina brevicauda*) were captured in lowland plots and one was captured in an upland plot. One Eastern Chipmunk (*Tamias striatus*) was captured in each forest type.

Small mammal captures in pitfall traps also were similar between upland and lowland sites (p = 0.65; Table 2). White-footed Mouse, Southern Red-backed Vole (*Myodes gapperi*), and Smoky Shrew (*Sorex fumeus*) were captured in similar numbers in upland and lowland pitfall traps. Captures of Masked Shrew (*Sorex cinereus*) tended to be higher on upland sites, whereas those of Short-tailed Shrew tended to be higher on lowland sites.

Table 3. Number of amphibians captured in pitfall arrays in lowland and upland forests of Fairy Stone State Park, Patrick County, Virginia.

Species	Lowland	Upland
Anaxyrus americanus	45	80
Lithobates sylvaticus	6	0
Lithobates clamitans	9	1
Lithobates palustris	6	0
Notophthalmus viridescens	3	3
Ambystoma maculatum	0	1
Plethodon cylindraceus	2	0
Plethodon cinereus	3	5
Pseudotriton ruber	3	1
TOTAL	**77**	**91**

Table 4. Number of reptiles captured in pitfall arrays in lowland and upland forests of Fairy Stone State Park, Patrick County, Virginia.

Species	Lowland	Upland
Terrapene carolina	1	0
Plestiodon fasciatus	3	5
Scincella lateralis	0	2
Carphophis amoenus	1	2
Storeria occipitomaculata	1	0
Diadophis punctatus	0	2
Pantherophis alleghaniensis	1	0
TOTAL	**7**	**11**

Amphibians in pitfall traps were dominated by the American Toad (*Anaxyrus americanus*), most of which were juveniles (Table 3). Overall, amphibian captures were significantly higher on upland sites (p = 0.08). This result was mostly due to higher captures of juvenile American Toads on one upland site compared to its paired lowland site, but there was not an overall difference in American Toads between forest types (p = 0.32). Frogs (all in the genus *Lithobates*) were much more numerous on lowland sites (Table 3), but mostly due to one site and not significantly different between lowland and upland sites (p = 0.30). Pitfall captures of salamanders were similar between upland and lowland sites and identical for Red-Spotted Newts (*Notophthalmus viridescens*). This was surprising given the high number of incidental observations of terrestrial juveniles (efts) of this species in many areas of the park. Incidental captures of salamanders in streams on lowland sites included Seal Salamander (*Desmognathus monticola*), Northern Dusky Salamander (*Desmognathus fuscus*), Southern Two-lined Salamander (*Eurycea cirrigera*), and Three-lined Salamander (*Eurycea guttolineata*).

Captures of reptiles in pitfall traps were low and not significantly different between treatments (p = 0.27; Table 4). The most commonly captured reptile was the Common Five-lined Skink (*Plestiodon fasciatus*). Only small snakes or juveniles of larger snakes were captured in pitfall traps. Two incidental observations of Northern Water Snakes (*Nerodia sipedon*) were made in lowland forests near Fairy Stone Lake. Other incidental observations of snakes during the study period included a Black Racer (*Coluber constrictor*) found within the lower slope forest and Northern Copperhead (*Agkistrodon contortrix*) and Timber Rattlesnake (*Crotalus horridus*); the latter two species were found on roads.

DISCUSSION

Lowland and upland communities of birds, and terrestrial small mammals, amphibians, and reptiles differed little in abundance and species richness. Most differences were in species composition, and mainly among amphibians and birds.

Unexpectedly, one of the few significant differences was a higher abundance of amphibians on upland sites compared to lowland sites. Some of this difference was attributable to numerous juvenile toads at a sampling site near a water retention pond in the center of the park. The retention pond is the presumed natal habitat of these toads due to calling activity observed there earlier in the year. While the pond is equidistant from the upland and lowland pitfall trapping arrays, toads that happened to disperse from the south side of this pond could take a direct travel path uphill to the upland site. To reach the lowland site, however, toads would need to leave from the south side of the pond, travel approximately 100 m, and then move along the base of a hill to the lowland site. American Toads represented 73% of all amphibian captures and 59% of all American Toads were captured near the site closest to the pond. The upland site had 92% of all captures of toads within this upland-lowland pair. The pond is also the presumed source of Green Frogs and Pickerel Frogs, due to observations of calling activity earlier in the year, but frogs are less tolerant of dry conditions and of dehydration than toads (Schmid, 1965; Bentley & Yorio, 1976; Gatten, 1987) and likely stayed in the damper lowland areas, perhaps resulting in more captures at lowland sites. Nearly 80% of all frog captures occurred on the lowland trapping array near this pond. If toads are removed from the totals, there were nearly three times the captures of amphibians in lowland plots (32) compared to upland plots (11). Although not captured in traps, Spring Peeper (*Pseudacris crucifer*) and Upland Chorus Frog (*Pseudacris feriarum*) were observed in the park in the spring of 2010.

Stream-dwelling salamanders were not captured in any pitfall traps because they rarely travel far from the stream channel (T. Fredericksen, pers. obs.), but we found them to be very abundant in streams in the park and found four species during stream searches. Among terrestrial salamanders, it was interesting to note that White-Spotted Slimy Salamanders (*Plethodon cylindraceus*) and Red Salamanders (*Pseudotriton ruber*) were captured more frequently on lowland sites, but the Red-backed Salamander (*Plethodon cinereus*) was captured more commonly on upland sites, but this could be an artifact of small sample size. In a study in Pennsylvania, Ross et al. (2000) found a higher abundance of Red-backed Salamanders, and terrestrial salamanders in general, in more mesic northern hardwood stands compared to drier oak-hickory stands. Requiring moist soils, leaf litter, or cover objects to breathe and for reproduction (Beane et al., 2010), it was expected that they would have been more abundant in lowland forests.

Captures of some species were lower than expected, particularly Red-Spotted Newts, given their observed abundance in the park, as well as some common frog species, such as Green Frogs and Pickerel Frogs. Using the same pitfall trapping strategy, Fredericksen et al. (2010) recorded large numbers of these species in the forests of Ferrum College, approximately 20 km north of the park. Gibson & Sattler (2007) recorded Marbled Salamanders (*Ambystoma opacum*) in the park, but we did not observe that species in this study.

Interior forest bird species, such as Red-eyed Vireo and Ovenbird, were equally dominant in upland and lowland forests. Tufted Titmouse, among the most abundant species, is considered a mature forest generalist (Murray & Stauffer, 1995), but it had a higher abundance in lowland forests. As expected from their preference for streamside habitats (Murray & Stauffer, 1995), Acadian Flycatcher and Louisiana Waterthrush were present only on lowland or transitional sites. In a study conducted in nearby counties, Fredericksen (2008) also observed that American Redstarts were more common in mesic, lowland forests. The Wood Thrush was only detected on lowland sites. This species is more common in mesic forests (Murray & Stauffer, 1995). Other bird species had higher abundances on upland sites. Some species, such as the Great-Crested Flycatcher and Blue-headed Vireo, have been associated with upland oak forests (Murray & Stauffer, 1995). Rodewald (2003) noted an expected preference of bark-foraging bird species for oak forests due to their furrowed bark, which provides more opportunities for insect foraging and for caching food in furrowed or loose bark. The higher abundance of bark-foraging birds on upland sites, such as Hairy Woodpecker and Black-and-White Warbler, supports this hypothesis, but other bark-foraging and seed-caching species, such as Tufted Titmouse, Carolina Chickadee (*Poecile carolinensis*), and White-breasted Nuthatch (*Sitta carolinensis*), did not show preferences for upland forests.

Small mammal captures in Sherman traps consisted predominantly of the White-Footed Mouse. This species was also the most commonly captured mammal in pitfall traps. The number of captures was similar in upland and lowland forests, which was expected because this species is considered to be a habitat generalist (Adler & Wilson, 1987; Menzel et al., 1999).

Some studies, however, have reported a relationship between population levels of this and other species, such as Eastern Chipmunk, to acorn yield (Ostfeld et al., 1996; McShea, 2000; Schnurr et al., 2002), which suggests that upland oak forests may support higher levels of these populations during mast-producing years. Shrew species were commonly captured in pitfall traps. The Smoky Shrew was captured in similar numbers in upland and lowland forests. The Masked Shrew was captured more often in upland forests and the Short-tailed Shrew was captured more commonly in lowland forest sites, although both of these species are considered to be habitat generalists (Mitchell et al., 1997; Menzel et al., 1999). Again, captures of small mammal species were relatively low compared to captures in a study of forests at Ferrum College (Fredericksen et al. 2010) using the same trapping methods.

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Amphibians and Reptiles of the Eastern Shore of Virginia National Wildlife Refuge and Fisherman Island National Wildlife Refuge

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ABSTRACT

I conducted an inventory of amphibians and reptiles in 2006 at Eastern Shore of Virginia National Wildlife Refuge (ESVNWR) and Fisherman Island National Wildlife Refuge (FINWR), Virginia to document their occurrence, describe their associated habitats, and provide refuge staff with conservation and management recommendations. Forty species (12 frogs, 4 salamanders, 8 turtles, 4 lizards, and 12 snakes) were expected to occur at ESVNWR and FINWR on the basis of published distribution patterns. The proportion of expected species documented was 67% for frogs, 0% for salamanders, 88% for turtles, 25% for lizards, and 75% for snakes. Low encounter rates with secretive species, variation in regional distribution patterns, and history of intensive land use at ESVNWR likely contributed to the low species richness for salamanders and lizards. Only five species of reptiles were documented at FINWR. I summarize numerous life history and natural history observations on all species accumulated during the inventory on each refuge and suggest additional research that would benefit the region's herpetofauna.

Key words: Amphibians, biogeography, ecology, *Malaclemys terrapin*, natural history, reptiles, inventory, endangered species, resource management.

INTRODUCTION

Although some of the national wildlife refuges in the United States have conducted field research on their existing flora and fauna (e.g., Buhlmann & Gibbons, 2006), many have never completed baseline species inventories. Where information exists, it is often incomplete and inaccurate as is also the case with many national parks (Mitchell, 2000b). For refuge managers to effectively maintain the biological diversity and ecological health of their refuges, they must have a basic knowledge of the natural resources that occur there, as well as an understanding of those factors that may threaten them. Many of the wildlife refuges in the eastern United States are located on land formerly used for agriculture and other intensive human uses. Such lands have changed from farmland through ecological succession to a mosaic of habitats. Restoration on refuges has usually been limited to construction of waterfowl ponds and maintenance of fields of grasses and other plants for waterfowl forage (JCM pers. obs.). Amphibians and reptiles are seldom included in management plans, although many species have responded well to restoration activities and the natural succession that has been allowed to occur (Cook, 2008). Thus, national wildlife refuges provide important habitats for these two groups of vertebrates and in many places offer refugia from surrounding inhospitable land use.

The Eastern Shore of Virginia National Wildlife Refuge (ESVNWR) lies on the southern tip of the Delmarva Peninsula and is bordered on the east by the Atlantic Ocean and on the west by the Chesapeake Bay. Prior to European colonization, the Eastern Shore supported a deciduous mixed hardwood forest (Wesler et al., 1981). During the exploration and early settlement period of the 17th and 18th centuries, forests were cleared for agriculture for production of grain and livestock and, to a lesser extent, tobacco. The majority of the farmland on the current refuge became Fort John Custis Army Base in 1940, and later became the Cape Charles Air Force Base. Aerial photographs show that

land on the western portion of the base was farmed from the 1960s to 1990 (Mata, 1997). The U.S. Fish and Wildlife Service acquired the land in the 1980s and ESVNWR was established officially in 1984 (U.S. Fish and Wildlife Service, 2005). The refuge administered a cooperative farming program on approximately 30 ha from 1984 to 1990 for sorghum, millet, milo, and sunflower that were planted and rotated with legumes (i.e., red clover) for wildlife consumption (http://training.fws.gov/library/CCPs/eastshoreVA_ index.htm, accessed 6 June 2006). Farming was discontinued on the refuge in 1990 and the fields were left fallow.

The earliest documentation of the existence of Fisherman Island is in navigational charts of the Chesapeake Bay published in 1815. Thus, it is apparently of modern origin. In 1886, the federal government purchased the island from its owner William Parker for an immigrant quarantine station but it was used only once in the treatment of yellow fever victims from the ship *Despa* in 1893. Soldiers from the Fourth Company of the Virginia Coastal Artillery National Guard were stationed on the island to protect the entrance of the Chesapeake Bay at the advent of World War I in 1914. The U.S. Navy used the island as a harbor defense unit and, with the entry of the United States into World War II, as a submarine detection base. In 1943, long cables (still present) from structures on the island controlled the movement of nearly 300 underwater mines, Four radar-controlled 90-millimeter guns were also installed by the Army. The artillery station was deactivated in 1944 and the land was transferred from the Army to the Navy, which maintained a LORAN radar navigation station on the island until 1969. Fisherman Island National Wildlife Refuge (FINWR) was established in 1969 and transferred to the Department of the Interior in 1973 (U.S. Fish and Wildlife Service, 2005).

A primary goal of the amphibian and reptile inventory on these two refuges was to provide a reliable species list for each based on a combination of published literature, museum records, and fieldwork. This paper summarizes species occurrence, habitat use, and natural history observations for these vertebrates on ESVNWR and FINWR.

MATERIALS AND METHODS

Study Area

ESVNWR and FINWR are located on the lower end of the Delmarva Peninsula in Northampton County, Virginia (Fig. 1). ESVNWR encompasses 465.4 ha on the tip of the mainland and FINWR is a 749 ha barrier island at the mouth of the Chesapeake Bay. Removal of military structures was initiated when the ESVNWR was established to create habitat to support migrating birds and other wildlife. Residences, towers, a non-commissioned officer's club, tennis court, swimming pool, bowling alley, and over 100 military structures were removed or demolished. Most of the once-developed land has changed via natural succession, much of which has become seedling Loblolly Pine (*Pinus taeda*) and shrub habitat. Invasive plant species such as Japanese Honeysuckle (*Lonicera japonica*), Fescue Grass (*Festuca* spp.), Common Reed (*Phragmites communis*), and Kudzu (*Pueraria lobata*) have become established throughout much of the disturbed acreage of the former base and farmland. Other invasive species include Autumn Olive (*Elaeagnus umbullata*), Multiflora Rose (*Rosa multiflora*), Mustards, Fennel (*Foeniculum vulgare*), and *Lespedeza sp.*

ESVNWR is approximately 35% wooded, scrub-shrub, 65% open fields in various stages of succession, and salt marsh. The refuge supports a variety of mixed species grasslands, Loblolly Pine stands, mixed Loblolly Pine and hardwood (various oaks [*Quercus* spp.], hickories [*Carya* spp.], and Black Cherry [*Prunus serotina*]) stands, brackish marsh fringe on the eastern and southern edges, a large freshwater depression, one freshwater pond (North Pond), a freshwater slough and swamp, areas of mowed grass, paved and gravel roads, and several buildings, most of which were erected for the refuge. North Pond (ca. 1 ha) is usually permanent but fluctuates dramatically and occasionally dries completely. It is an artificial pond that fills only partially during rainfall events. The large freshwater depression adjacent to the Visitor's Center was a shallow pond but is drained and now supports sedges and grasses. It has standing water during and only for short periods after rain events. This pond is artificial and water may be pumped into it. There are several pools with varying salinity at the southern end of the mainland amongst Loblolly Pine stands. Common Reed has invaded the southernmost portion of the refuge. The freshwater slough and swamp within the southern portion of the mainland supports duckweed (*Lemma* spp.) and emergent shrubs (e.g., *Clethra alnifolia* [Pepperbush]).

FINWR is surrounded by *Spartina* marsh on all but the Chesapeake Bay side of the island, which is beach habitat. The upland portion of the island is sand with about 80% wooded and shrub and 20% open, sandy areas with scattered Beach Grass (e.g., *Panicum* spp.). Active dunes occur only in the northeast and southeast portions of the island. The rest of the upland habitat is stabilized dunes and most support several hardwood

Fig. 1. Map illustrating the southern tip of the Delmarva Peninsula and associated islands that comprise the ESVNWR and FINWR. Map derived from Google Earth, Version 2009.

trees (e.g., *Morella* spp., *Prunus* spp., *Baccharis halimifolia* [Groundseltree]) that dominate the vegetation on the high side of the island. These trees and shrubs (e.g., *Amelanchier* [Serviceberry]) often occur as clumps and provide cover for birds and other wildlife. Belden & Field (2007) described the flora and vegetative communities of FINWR, indicating that 30% of the plants are invasive. U.S. Route 13 bisects the upland portion of the island on the northwestern end. Approximately 16.4 ha lie above the mean high water line. This southernmost barrier island in Virginia is separated from ESVNWR by Fisherman's Inlet, a half-mile-wide body of ocean water. Onshore sand bar movement (accretion) continues to expand the island's size, currently estimated at 749 ha. (http://training.fws.gov/library/CCPs/eastshoreVA_ index.htm).

Habitats

I describe eight habitat types used by amphibians and reptiles on ESVNWR and FINWR. Common and scientific names of the flora follow Radford et al. (1968) and Stuckey & Gould (2000). The habitat codes are provided for each species below.

Grasslands (GRA) - Open fields dominated by grasses that are mowed on a regular to irregular basis or other land uses that have removed the forest canopy and created small to large patches of grass habitat. These areas include mixed grasses (Bermuda Grass [*Cynodon dactylon*], Velvet Grass [*Holcus lanatus*], Sweet Vernal Grass [*Anthoxanthum odoratum*], and Broomsedge [*Andropogon virginicus*]). Herbs include Horseweed (*Erigeron canadansis*), Pigweed (*Amaranthus hybridus*), Goldenrod (*Solidago* spp.), Fennel, Pokeweed (*Phytolacca americana*), Dog Fennel (*Anthemis* sp.), St. John's Wort (*Hypericum* sp.), Wood Sorrel (*Oxalis* sp.), and Dandelion (*Taraxacum officinale*) (B.D. Watts, pers. comm.). Other commonly found species include Wax Myrtle (*Morella cerifera*), patches of Black Raspberry (*Rubus occidentalis*), and Blackberry (*Rubus* spp.), Eastern Red Cedar (*Juniperus virginiana*), Japanese Honeysuckle, Multiflora Rose, Autumn Olive, Willow (*Salix* spp.), Sumac (*Rhus glabra*), and Common Nightshade (*Solanum* spp.).

Mixed hardwoods and pine (MHP) - Loblolly Pine and Virginia Pine (*Pinus virginiana*) comprise most of the coniferous forest elements of this habitat type. Dominant hardwood trees include White Oak (*Quercus alba*), Southern Red Oak (*Q. falcata*), Black Oak (*Q. velutina*), Willow Oak (*Q. phellos*), and Black Cherry. Understory trees include American Holly (*Ilex opaca*), Wax Myrtle, Dogwood (*Cornus florida*), Red Maple (*Acer rubrum*), Sweetgum (*Liquidambar styraciflua*), and Yellow Poplar (*Liriodendron tulipifera*). Several ephemeral pools (natural depressions in the landscape that hold water for varying times during the year, usually winter to summer) occur in this habitat type, varying in hydrology from short hydroperiods (weeks) to long hydroperiods (> 6 months) but usually drying out by the end of summer in most years.

Mixed pine (MPI) - Loblolly Pine is the most common pine species at ESVNWR, but some areas are largely composed of Virginia pine. In some areas, hardwood trees (Black Cherry, Red Maple) are scattered among the pines, usually as understory trees. Ground vegetation is sparse and includes Pennsylvania Smartweed (*Polygonum pensylvanicum*) and Partridge Berry (*Mitchella repens*).

Impoundments (IMP) - The only impoundments at ESVNWR are North Pond (Fig. 2), the depression pond adjacent to the Visitor's Center, and the shallow freshwater area immediately east and west of Wise Point Road. They all dry in drought years, although North Pond holds water long and often enough to allow frogs with long larval periods (e.g., *Lithobates catesbeianus*) to survive.

Fig. 2. North Pond on ESVNWR showing shallow water and the surrounding vegetation. This pond is ephemeral but supports a high diversity of amphibians and reptiles. Photo by J.C. Mitchell.

Swamp (SWP) - Swamp habitat in ESVNWR is most often flooded hardwoods in stream and bottomland areas. Mixed hardwoods such as Red Maple and Pepperbush, and fluctuating hydrologies characterize swamp habitats in this region. The primary swamp in the refuge is located adjacent to Wise Point Road below the road entrance gate (Fig. 3).

Vegetated Dune (VDU) – The dunes on FINWR support a variety of shrubs and grasses (Fig. 4). Vegetation on the primary dune ridge, which lies landward of the beach/foredune zone along crests of low ridges, is usually sparse or clumped and mainly colonized with grasses that have the ability to propagate via rhizomes and can withstand deep sand burial. The predominant species are American Beach Grass (*Ammophila breviligulata*), Running Panic Grass (*Panicum* sp.), and Salt Grass (*Distichis spicata*).

Fig. 3. Wetland at the southern end of the ESVNWR about 150 m N of the southern tip of Delmarva. Frogs heard or observed at this site were *Gastrophryne carolinensis*, *Hyla cinerea*, and *Hyla squirella*.

Fig. 4. Active dunes on FINWR illustrating the patchiness of the hardwoods and herbaceous vegetation. Photo by J.C. Mitchell.

Primary swales also have sparsely distributed shrubs, mainly Wax Myrtle and Bayberry (*Myrica pennsylvanica*). Plants have stabilized most of the dunes on the island except for the area near the entrance gate. This area has active dunes that support Black Cherry, Serviceberry, Prickly Pear Cactus (*Opuntia sp.*), Wax Myrtle, and patches of grasses.

Marsh (MAR) – The brackish marsh around most of FINWR and a portion of the ESVNWR is dominated by Cordgrass (*Spartina alterniflora*), Saltmeadow Cordgrass (*Spartina patens*), Hay, Black Rush (*Juncus gerardii*), and scattered Hightide Bush (*Iva frutescens*). The marsh is interspersed with mudflats and tidal channels of varying depths depending on tidal cycles.

Beach (BEA) - The beach on the Chesapeake Bay side of FINWR extends outward from the dunes and lacks vegetation. The intersection of these two zones is usually abrupt with the dunes rising sharply above the beach. The transition zone near the southern end of the island is less dramatic.

Field Sampling

I used various sampling techniques to conduct the inventory at ESVNWR and FINWR from March to October 2006. The techniques are described briefly here and in detail for amphibians by Heyer et al. (1994) and Mitchell (2000a), and for reptiles by Jones (1986), Mitchell (1994), and Blomberg & Shine (1996). Audio surveys were conducted during the day and also at night by listening for frog vocalizations at known wetland sites. Audio surveys conducted as part of this inventory were not time-constrained. Several species were detected opportunistically by driving roads during day

or night. I captured adult and larval anurans by sampling aquatic habitats with dipnets. I set unbaited standard minnow traps in shallow water with the upper portion set above the water surface to prevent drowning of air-breathing animals. Funnel openings were enlarged to 25-30 mm to increase capture success of adult frogs and semi-aquatic snakes. Minnow traps were also used in terrestrial habitats to capture snakes. Standard turtle hoop traps were set in wetlands and removed the next day. Traps used were (1) single funnel opening with nylon mesh on three 30-inch diameter steel hoops (nylon turtle nets) and (2) single funnel opening with nylon mesh on four 20-inch diameter fiberglass hoops (mini-hoop nets for catfish). Traps were baited with a can of sardines and set so that a portion was above the water surface to prevent turtles from drowning. When the probability of encounter was high (appropriate weather and season for the targeted species), I conducted visual encounter surveys (VES) by walking randomly through a selected habitat type, as well as turning logs and other surface objects to uncover animals. Binoculars were used to search water surfaces, logs, margins of wetlands, and basking sites for frogs, lizards, snakes, and turtles. Visual encounter surveys conducted as part of this inventory were not time-constrained.

I identified all captured amphibians and reptiles to species and released them at their capture sites. Common and scientific names follow Crother (2008). Most animals were measured (mm), weighed (g), and sexed. Body and tail measurements of amphibians were taken using plastic rulers, metric tapes, and calipers. I obtained body weights with Pesola® scales and an Ohaus Scout electronic field balance. Animals seen or heard in the field but not captured were recorded simply as observations.

RESULTS

Twelve species of frogs, four species of salamanders, eight species of turtles, four species of lizards, and twelve species of snakes were expected to occur on ESVNWR and FINWR based on available habitat types and species known to occur in Northampton County, Virginia (Mitchell, 1994; Conant & Collins, 1998; Mitchell & Reay, 1999; Roble et al., 2000; Roble 2001; White & White, 2002; Gibson, 2011) (Table 1). The list of species in the Comprehensive Conservation Plan (CCP) for these refuges includes 11 frogs, two salamanders, seven turtles (including four sea turtles), four lizards, and 11 snakes (Appendix D, U.S. Fish and Wildlife Service, 2008). Except for the species noted below, all amphibians and reptiles listed in the CCP were documented during this inventory. Three species of sea turtles (Green Sea Turtle [*Chelonia mydas*], Leatherback Sea Turtle [*Dermochelys coriacea*], Kemp's Ridley Sea Turtle [*Lepidochelys kempii*]) occasionally occur as rare strandings on Fisherman Island National Wildlife Refuge (Mitchell, 1994; Mitchell & Reay, 1999), but they were not encountered during my study.

During the 2006 inventory, I documented eight species of frogs and 17 species of reptiles (Table 1). Reptiles included seven species of turtles, one lizard, and nine species of snakes. No salamanders were found. Total capture success was 67% of the expected species of frogs in Northampton County and 71% for reptiles (88% for turtles, 25% for lizards, and 75% for snakes). Four species of frogs known to occur on the lower Eastern Shore were not encountered during this inventory (*Acris crepitans*, *Hyla chrysoscelis*, *Pseudacris kalmi*, *Scaphiopus holbrookii*). I documented all of the expected turtles except for the Spotted Turtle (*Clemmys guttata*) and the three species of sea turtles noted above. I encountered only one (*Scincella lateralis*) of the four expected lizards on ESVNWR and FINWR (*Plestiodon fasciatus*, *Plestiodon laticeps*, and *Sceloporus undulatus* were not found). The only expected snakes that were not captured during my inventory were the Northern Copperhead (*Agkistrodon contortrix mokasen*), Ring-necked Snake (*Diadophis punctatus*), and Eastern Gartersnake (*Thamnophis s. sirtalis*). Two species of turtles and three species of snakes were documented on FINWR, whereas eight species of frogs, six turtles, one lizard, and eight snakes were documented for ESVNWR (Table 1).

Species Accounts

Habitat codes included in the habitat descriptions above are used for brevity.

<u>Anurans</u>

Anaxyrus fowleri (Fowler's Toad) - GRA, MHP, MPI, IMP

Fowler's Toads were abundant on ESVNWR and observed April-September. Many individuals were observed on roads at night, in mowed grass areas, and in natural habitats throughout the refuge. Calling males were heard between 11 April and 27 June. Mating was observed on 9 June and 26 June. Eggs were observed in North Pond on 11 April and tadpoles were observed on 19 October. Sixteen tadpoles measured 9-13 mm total length and were in Gosner developmental stages 24-25.

Table 1. Checklist of the amphibians and reptiles of Eastern Shore of Virginia National Wildlife Refuge and Fisherman Island National Wildlife Refuge, Virginia. Expected (X) species are those known to occur in Northampton County (Mitchell & Reay, 1999; Roble et al., 2000; Roble, 2001; White & White, 2002; Gibson, 2011). Species that were confirmed by capture or observation in each refuge are noted as "O." Three species of sea turtles that are occasionally found on Fisherman Island are not included in this list.

Scientific name	Common name	Northampton County	ESVNWR	FINWR
Frogs				
Acris crepitans	Northern Cricket Frog	X		
Anaxyrus fowleri	Fowler's Toad	X	O	
Gastrophryne carolinensis	Eastern Narrow-mouthed Toad	X	O	
Hyla chrysoscelis	Cope's Gray Treefrog	X		
Hyla cinerea	Green Treefrog	X	O	
Hyla squirella	Squirrel Treefrog		O	
Pseudacris crucifer	Northern Spring Peeper	X	O	
Pseudacris kalmi	New Jersey Chorus Frog	X		
Lithobates catesbeianus	American Bullfrog	X	O	
Lithobates clamitans	Northern Green Frog	X	O	
Lithobates sphenocephalus	Southern Leopard Frog	X	O	
Scaphiopus holbrookii	Eastern Spadefoot	X		
Salamanders				
Ambystoma opacum	Marbled Salamander	X		
Hemidactylium scutatum	Four-toed Salamander	X		
Notophthalmus viridescens	Red-spotted Newt	X		
Plethodon cinereus	Red-backed Salamander	X		
Turtles				
Caretta caretta	Loggerhead Sea Turtle	X		O
Chelydra serpentina	Common Snapping Turtle	X	O	
Chrysemys picta	Eastern Painted Turtle	X	O	
Clemmys guttata	Spotted Turtle	X		
Kinosternon subrubrum	Eastern Mud Turtle	X	O	
Malaclemys terrapin	Diamond-backed Terrapin	X	O	O
Pseudemys rubriventris	Red-bellied Cooter	X	O	
Terrapene carolina	Eastern Box Turtle	X	O	
Lizards				
Plestiodon fasciatus	Common Five-lined Skink	X		
Plestiodon laticeps	Broad-headed Skink	X		
Sceloporus undulatus	Eastern Fence Lizard	X		
Scincella lateralis	Ground Skink	X	O	
Snakes				
Agkistrodon contortrix	Northern Copperhead	X		
Carphophis amoenus	Eastern Worm Snake	X	O	
Coluber constrictor	Northern Black Racer	X	O	O
Diadophis punctatus	Northern Ring-necked Snake	X		
Heterodon platirhinos	Eastern Hog-nosed Snake	X	O	
Lampropeltis getula	Eastern Kingsnake	X	O	
Nerodia sipedon	Northern Watersnake	X	O	
Opheodrys aestivus	Rough Greensnake	X		O
Pantherophis alleghaniensis	Eastern Ratsnake	X	O	O
Storeria dekayi	Northern Brownsnake	X	O	
Thamnophis sauritus	Northern Ribbonsnake	X	O	
Thamnophis sirtalis	Eastern Gartersnake	X		

The largest male was 62 mm SVL and weighed 24.7 g and the largest female was 73 mm SVL and weighed 35.2 g. However, the heaviest female was 72 mm SVL and weighed 41.5 g. The smallest mature male measured 49.5 mm SVL and weighed 13.8 g. The smallest presumably mature female measured 51 mm SVL and weighed 15.5 g. The largest five immature females were 45-49 mm SVL and weighed 7.9-12.8 g. The smallest Fowler's Toad captured was 26 mm SVL and weighed 1.6 g on 28 June. One female was missing her right rear foot. A 72 mm female died while trying to consume a 55 mm total length, 1.6 g grasshopper on 26 June. She also contained 2 small beetles, a small caterpillar, and 3 isopods (pill bugs).

Gastrophryne carolinensis (Eastern Narrow-mouthed Toad) - GRA, MHP, MPI

Narrow-mouthed Toads were commonly heard calling throughout the late spring and summer months. They called from small bodies of water in pine and cedar lowlands, as well as in ditches near the southern end of the refuge. A female was found under a board in a grass field on 9 June. Adults were heard calling 27 May - 27 June throughout ESVNWR. Choruses were present at several locations in shallow wetlands immediately east and west of Wise Point south to nearly the tip of the mainland. Amplexus was observed on 9 and 27 June. The largest male was 28 mm SVL and 1.5 g; the largest female was 32 mm SVL and 2.6 g.

Hyla cinerea (Green Treefrog) - GRA, MHP, MPI, IMP, MAR

Green Treefrogs were abundant on ESVNWR. Juveniles and adults were commonly seen on the sides and windows of houses and other structures. Adults were heard calling from trees and vegetation in and around North Pond and usually throughout ESVNWR south to the tip of the mainland from 18 May to 7 September. The largest adult male was 50 mm SVL and 6.3 g, and the largest adult female was 52 mm SVL and weighed 6.8 g (gravid). Amplexus was observed on 26 and 27 June. One male observed at North Pond on 25 March 2006 had three unidentified leeches attached to its abdomen (Fig. 5).

Hyla squirella (Squirrel Treefrog) - GRA, MHP, MPI, IMP

Squirrel Treefrogs were documented on the Delmarva Peninsula for the first time with discovery of a very large population in ESVNWR (Mitchell & Denmon, 2007). This species is abundant and found in all habitat types on the refuge. Several were found on windows of houses. Some called from small bodies of water in pine and cedar lowlands, as well as in ditches near the southern end of the refuge and from hardwood trees. Adults were heard calling 27 May - 7 September throughout ESVNWR south to the tip of the mainland. Mating behavior was observed on 9 June. The largest male was 35 mm SVL and 2.8 g, and the largest female was 36 mm SVL and 2.8 g (gravid). Metamorphs were observed on 19 October at North Pond.

Fig. 5. A male *Hyla cinerea* with three unidentified leeches on its abdomen found at North Pond on ESVNWR.

Lithobates catesbeianus (American Bullfrog) - GRA, IMP

The deepest portion of North Pond was the only location where this highly aquatic species was heard calling on 26 June. The next day a large (133 mm SVL, 284 g) female was caught on a paved road on ESVNWR during a heavy rainstorm.

Lithobates clamitans melanota (Northern Green Frog) - GRA, IMP, SWP

Adult Green Frogs were observed calling in North Pond on 26 June and 7 September in thick vegetation. Tadpoles were captured in the swamp/slough near the southern end of the mainland on 19 May. Some of these had rear legs indicating they were the 2005 breeding

cohort and would metamorphose in 2006. Only one male was captured (66 mm SVL, 23.7 g).

Lithobates sphenocephalus (Southern Leopard Frog) - GRA, MHP, MPI, IMP

Southern Leopard Frogs called from North Pond on 22 March, 11 April, 18 May, and 7 September. One calling male was observed perched above the water line by holding the stiff stems of an aquatic plant; they are usually sitting in shallow water. Egg masses were observed on 11 April (fresh and hatching) and tadpoles occurred in the pond on 19 May, 26 June, and 19 October. Six tadpoles measured 18-26 mm total length and were in Gosner developmental stage 25. One metamorph with tail was observed on 19 May. The largest male was 60 mm SVL and 16.9 g, and the largest female was 61 mm SVL and 17 g.

Pseudacris crucifer crucifer (Northern Spring Peeper) - GRA, MHP, MPI, IMP, SWP

Spring Peepers were first heard calling on ESVNWR on 22 March from North Pond and the depressional wetland adjacent to the Visitor's Center. Tadpoles were observed on 11 April in North Pond. The largest individual captured was a female (28 mm SVL, 1.9 g).

Turtles

Caretta caretta (Loggerhead Sea Turtle) - BEA

One Sea Turtle crawl was observed on the beach at FINWR on 5 July 2006 on the northeast side of the island. Skeletal elements are occasionally seen on the bayside.

Chelydra serpentina serpentina (Common Snapping Turtle) - IMP

Two Snapping Turtles were captured in turtle traps on 18 May in North Pond. A very large male (~300 mm CL) was observed in North Pond on 26 June. The largest captured male had a maximum CL of 182 mm, maximum PL of 128 mm, and weighed 1250 g.

Chrysemys picta picta (Eastern Painted Turtle) - IMP

Painted Turtles were common in North Pond but found nowhere else in ESVNWR. Eight were captured during the day and night while they rested on the bottom of the pond in shallow water (<0.5 m) in vegetation or in small indentations in the soft substrate. One 153 mm CL, 402 g female was found crossing a dirt road on 27 June at 1242 EDT; she had already nested. Of the 31 adults captured, 12 were males (mean CL = 138.8$\pm$15.8 mm, 101.3-157.1; mean PL = 127.3$\pm$13.0 mm, 98.0-141.7; mean body mass = 329.2$\pm$89.8 g, 148-485) and 19 were females (mean CL = 160.0$\pm$6.9 mm, 147.0-171.5; mean PL = 147.8$\pm$6.3 mm, 135.6-155.7; mean body mass = 531.6$\pm$58.3 mm, 402-600, n = 18). Two immature females (108 mm CL, 99 mm PL, 173 g, and 97 mm CL, 93 mm PL, 131 g) were judged to be in their fourth year of growth based on counts of lines of arrested growth. One mature male (101 mm CL, 98 mm PL, 148 g) was in his third year of growth. The only hatchling captured was 28.4 mm CL, 26.4 mm PL, and 5.7 g. A portion of two of the marginals on one female had been chewed by a predator, another female was missing her right foreleg and her left rear leg, and one male had a damaged left rear foot. The shell of a juvenile apparently killed by a predator was found at North Pond on 11 April.

Kinosternon subrubrum subrubrum (Eastern Mud Turtle) - GRA, MHP, MPI, IMP

Mud Turtles are apparently terrestrial for long periods of time at ESVNWR, as none was observed during day or night forays in North Pond until 18 May when five were captured in turtle traps. A heavy rainstorm during the morning of 9 June triggered movement of 25 individuals (11 males, 14 females) into the pond that night. Several were observed in the northern portion of the pond adjacent to a Loblolly Pine forest that had been repeatedly checked several times that day and early evening. A total of 37 individuals was caught, 20 males (mean CL = 93.5$\pm$4.1, 84.1-98.6; mean PL = 80.6$\pm$3.7 mm, 71.6-85.2; mean body mass = 146.7$\pm$19.1 g, 101.0-170.0) and 17 females (mean CL = 91.5$\pm$5.7 mm, 82.8-101.7; mean PL = 83.6$\pm$6.1 mm, 71.1-93.6; mean body mass = 146.1$\pm$22.0 g, 111-185). The smallest male was 86 mm CL, 73 mm PL, and 109 g and the smallest female was 83 mm CL, 77 mm PL, and 123 g. No juveniles were encountered. The shell of an apparently predator-killed adult was found at North Pond on 11 April. One adult male had a slightly kyphotic shell.

Malaclemys terrapin terrapin (Diamond-backed Terrapin) - VDU, MAR, ROAD

Diamond-backed Terrapins appear to be common on FINWR. Numerous nests were observed on the island, primarily in the active dune area, after being destroyed by Raccoons (*Procyon lotor*) and possibly

other predators. Fifteen roadkills and six live adult females were found on U.S. Rt. 13 during the 2006 inventory. Sixteen adult females were observed on the beach, along the sand road bisecting the island, and in the dunes. Active females presumably seeking or returning from nest sites were observed between 27 May and 21 July. The largest female captured measured 206 mm CL and 191 mm PL, less than the largest reported for Virginia for carapace length (213 mm) but larger than the largest known plastron length (189 mm) (Mitchell, 1994). The smallest adult female measured 169 mm CL. Numerous Pillbugs (*Armadillilium vulgare*) were observed in several fresh egg shells left over from being eaten by predators on Fisherman Island, presumably eating the last of the albumin (Fig. 6).

Pseudemys rubriventris (Red-bellied Cooter) - MHP

One adult female Red-bellied Cooter was observed walking through the refuge near the Headquarters Building on 24 August. There is no permanent water on ESVNWR, so this observation is likely of a transient individual from a permanent pond north of the refuge.

Terrapene carolina carolina (Eastern Box Turtle) - GRA, MHP, MPI

Box Turtles are apparently common on ESVNWR. Two were observed near buildings and two were caught in Hav-a-Hart® traps set for Raccoons. Two small individuals were 74 mm CL each and 69 mm and 76 mm PL. The first was determined to be in its second and the other in its third year of growth based on lines of arrested growth. The largest adult captured was a 127 mm CL, 126 mm PL, 422 g female.

Fig. 6. Pillbugs (*Armadillilium vulgare*) presumably feeding on the albumin inside the egg shells of *Malaclemys terrapin* after the fresh eggs have been eaten by a predator on FINWR.

Lizards

Scincella lateralis (Ground Skink) - GRA, MHP

One adult female was found on a resident sidewalk on 21 April on ESVNWR and another was observed under a log in mixed hardwoods and pine woods on 28 June.

Snakes

Carphophis amoenus amoenus (Eastern Worm Snake) - MHP

One adult female was found inside a moist log in mixed hardwoods and pine at the northern end of ESVNWR near the Headquarters Building on 28 June.

Coluber constrictor constrictor (Northern Black Racer) - GRA, MHP, MPI, VDU

Black Racers are common at ESVNWR in grassy areas and also occur in the shrub zones on FINWR. One was observed active at 1257 EDT on 9 June in a Cattail (*Typha* sp.) pool. The largest individual caught on the mainland was a 1078 mm total length and 400 g male. A 1370 mm total length, 316 g adult female was captured in one of 60 minnow traps set overnight among Myrtle shrubs and grasses on Fisherman Island on 28 June.

Heterodon platirhinos (Eastern Hog-nosed Snake) - GRA, MHP, MPI

One blotched, adult female Eastern Hog-nosed Snake (647 mm total length, 164 g) was caught in a minnow trap set along an abandoned building in a grassland area on ESVNWR.

Lampropeltis getula getula (Eastern Kingsnake) - GRA, MHP

A large, adult male (1320 mm total length) was killed on 12 October by a vehicle on the access road in ESVNWR. Habitat was mixed pines and hardwoods on the east side of the road and grasslands on the west side.

Nerodia sipedon sipedon (Northern Watersnake) - GRA, MHP, IMP

Northern Watersnakes were observed in North Pond on 19 May and 26-27 June. The largest one caught was

a 975 mm total length, 405 g female. One juvenile measured 284 mm total length and weighed 9.1 g.

Opheodrys aestivus (Rough Greensnake) - VDU

Rough Greensnakes are known to occur on FINWR and probably on ESVNWR as well. Only one of these cryptic snakes was observed during this inventory, on Fisherman Island on 8 September. An adult specimen in the former Virginia Commonwealth University Herpetological Collection (now in the North Carolina Museum of Natural Sciences) was collected from Fisherman Island on 21 March 1982.

Pantherophis alleghaniensis (Eastern Ratsnake) - GRA, MHP, MPI, VDU

Eastern Ratsnakes are common on both refuges. Dates of observation on ESVNWR were 19 May, 9 June, and 9 July. One was caught in an unused shed, another in grassland, and a third in Loblolly Pine woods. One adult was observed in shrub and grass habitat on FINWR on 12 September. The largest female was 1280 mm total length and weighed 410 g. The latter, captured on 9 July, had consumed 3 Northern Bobwhite (*Colinus virginianus*) eggs measuring on average 25.1 x 31.8 mm and weighing 10.5 g. No males were captured. The dorsal blotch pattern on one large female (1256 mm total length, 431 g) was visible without body distention, whereas no blotches were visible in the other three large females (1280 mm, 1173 mm, 1142 mm).

Storeria dekayi dekayi (Northern Brownsnake) - GRA, MHP

An adult female was found dead on 7 November 2006 adjacent to a dormitory yard on ESVNWR. Local habitat was mowed lawn and shrub regrowth with Bayberry, Multiflora Rose, Fennel, and Japanese Honeysuckle.

Thamnophis sauritus sauritus (Northern Ribbonsnake) - GRA, MHP, IMP

An adult male (827 mm total length, 36.2 g) was observed foraging in the rain on the night of 27 June in the shallow Cattail and grass wetland adjacent to North Pond.

DISCUSSION

Amphibians and reptiles are highly seasonal animals whose activity patterns respond to changes in climate, temperature, and precipitation. Thus, a complete inventory of amphibians and reptiles can be a challenge for short-term surveys. Two of the four frog species (*Acris crepitans*, *Hyla chrysoscelis*) not encountered during this inventory are known to occur at the lower end of the Delmarva Peninsula (Mitchell & Reay, 1999; White & White, 2002). The other two anurans (*Pseudacris kalmi*, *Scaphiopus holbrookii*) inhabit northern Northampton County but may not occur at the lower end. The lack of any of the expected salamanders suggests that habitats on the refuge may not be suitable. All of the expected turtles are represented in the refuge except for *Clemmys guttata*, which requires ephemeral freshwater marshes and pools that apparently are not present there. They are known to occur on Hog Island (Conant et al., 1990; Mitchell, 1994), but their existence there may be historical. The putative record for the Eastern Six-lined Racerunner (*Aspidoscelis sexlineata*) in Northampton County in Mitchell & Reay (1999) is incorrect and was included inadvertently. *Plestiodon fasciatus* and *Plestiodon laticeps* are known from northern parts of Northampton County and*Sceloporus undulatus* has been documented in two sites near the ESVNWR (Mitchell, 1994; Mitchell & Reay, 1999). Thus, lack of observations of these diurnal, and often conspicuous, lizards in pine stands on the refuge was unexpected. Copperheads (*A. contortrix*) are known from the northern end of the county, and Ring-necked snakes and Eastern Gartersnakes (*T. sirtalis*) have been documented from the middle portion of the county (Mitchell, 1994; Mitchell & Reay, 1999; Roble, 2001). Historical land use in the lower portion of the Peninsula now occupied by present day ESVNWR may have played a role in determining their absence. However, each of these species may be found with additional inventory effort and, perhaps most likely, by opportunistic encounters. Snakes in general can be especially difficult to discover because many are secretive and occur in limited numbers (Gibbons et al., 1997). Leiden et al. (1999) demonstrated with multiple techniques that 66% of the total snake species expected were caught in the first 75 days of sampling, but that an additional 325 days of sampling would be required to collect 90% of the total number expected. One snake species was not discovered for 22 years on the Savannah River Site, an area that has been intensively studied for over 40 years (Whiteman et al., 1995; Gibbons et al., 1997).

An important factor to consider in amphibian conservation on ESVNWR is their movement between aquatic breeding sites and the terrestrial environment. Production of metamorphic frogs in breeding sites and their emergence into the terrestrial environment is a major energetic link between these two habitats

(Gibbons et al., 2006). Dispersal of these metamorphs occurs over long distances from which they return to their natal breeding sites or colonize other breeding sites (Semlitsch, 2008). Thus, maintenance of viable populations of these amphibians requires protection and management of all breeding sites in the area and the terrestrial habitat. Evaluation of breeding site location, terrestrial habitat for periods outside of the breeding period, and dispersal corridors should be included in any species management plan. Habitat conservation strategies for amphibians should also include the maintenance and preservation of a core habitat composed of breeding pools or ponds and the terrestrial habitat around them (>200 m), surrounded by an additional buffer zone of 100-200 m (Semlitsch & Jensen, 2001).

Threats to amphibians and reptiles at ESVNWR include mortality from vehicular traffic, human disturbance or killing, subsidized predators (e.g., raccoons that benefit from human shelter and discarded food [Mitchell & Klemens, 2000]), miscellaneous hazards that trap animals, crab pot mortality of *M. terrapin*, and habitat loss or alteration. Removal of animals by humans for personal purposes or the commercial pet trade constitutes an unknown level of threat because there are no data to evaluate this impact. Habitat loss is not considered a major threat at ESVNWR or FINWR. Future plans for alteration of areas of refuge land that may include habitat loss should be reviewed thoroughly and losses prevented when possible. Specific areas to which to pay special attention include all impoundments, breeding sites, swamps, and the pine-hardwood forests.

Vehicular traffic on all roads remains a threat to amphibians and reptiles crossing them. This includes U.S. Route 13 that bisects Fisherman Island and the roads within ESVNWR. Many frogs and several snakes were killed by vehicles in 2006. An evaluation of the magnitude of these threats should be undertaken and measures implemented to reduce the mortality of these animals. Road mortality is especially an issue with *Malaclemys terrapin*.

Several other local environmental issues affect the amphibians and reptiles on ESVNWR and FINWR. Trash in the form of plant and bird netting, netting from fisheries activities that washes up on the Fisherman Island beach, rip-rap, and other items that may trap reptiles and amphibians should be removed and discarded safely (Mitchell et al., 2006b). Mowing of grass areas to short heights is a potential hazard to frogs and some reptiles, particularly *Terrapene carolina*. Blade height should be no lower than 6 inches (Mitchell et al., 2006a). Invasive plants and introduced species pose mostly unknown threats to amphibians and reptiles. Giant Reed is well known to choke out native vegetation and modify habitats used by these vertebrates (Paton, 2005). Introduced animals include invertebrates and domestic and feral cats. The latter are usually not considered an introduced species but were introduced into North America by early colonists (Mitchell & Beck, 1992). Assessments of each invasive and introduced species should be undertaken with respect to amphibian and reptile management.

Long-term habitat management at ESVNWR would be beneficial to amphibians and reptiles if management issues and potential construction impacts were viewed within the context of the refuge's landscape matrix (Mitchell et al., 2006a). Any change to mixed hardwood and pine forests, impoundments, freshwater wetlands, tidal marshes, and dunes at ESVNWR and FINWR, for example, may have consequences to small snake assemblages and *T. carolina* populations. Many individuals of the latter species are long-lived and have low reproductive rates (30-100 years old; Dodd 2001). Mowing is a weekly, if not daily, activity at ESVNWR. Such operations are well-known to kill Box Turtles and other reptiles, such as large snakes.

The natural history of amphibians and reptiles has received little to no attention in most national wildlife refuges. Although my short-term inventory of these vertebrates on ESVNWR and FINWR has provided some information on their natural history, more research into their population dynamics would greatly benefit the development of a comprehensive natural habitat management plan. A management plan for amphibians and reptiles on these two refuges would help to ensure that these areas are maintained in sufficient natural conditions to allow the long-term persistence of the native herpetofauna.

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Patterns of Frog and Toad Vocalization in Fairfax County, Virginia

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ABSTRACT

Anuran (frog and toad) call surveys are used to monitor long-term trends in anuran populations but survey efficacy is reduced if peak calling periods are unknown. We estimated peak calling activity for eight species (American Toad, Green Treefrog, Cope's Gray Treefrog, American Bullfrog, Green Frog, Pickerel Frog, Southern Leopard Frog, and Spring Peeper) in Fairfax County, Virginia. We identified significant interspecific differences in detection probabilities and days to first detection. Spring Peeper and American Bullfrog were the first and last anurans to initiate calling, respectively. Sampling at least five times during two sampling windows (ca. 27 March-17 April and ca. 15 May-16 July) is needed for long-term anuran monitoring. Minimum threshold temperatures required for vocalization increased as the season progressed, even during conditions that supported chorusing in weeks prior. Surveys should be rotated to avoid temporal biases and not be conducted when temperatures are below minimum thresholds.

Key words: anuran, monitoring, calling anuran surveys, vocalization, calling chronology.

INTRODUCTION

Anuran call surveys (CAS) are widely used to monitor long-term trends in anuran (frog and toad) populations, both at smaller, local scales (Steelman & Dorcas, 2010; Cook et al., 2011) and larger, statewide (Weir et al., 2005), regional (Weir et al., 2005), and national scales (Weir & Mossman, 2005). CAS are especially important because changes in anuran calling chronology could be a possible first indication of a biotic response to climate change (Gibbs & Breisch, 2001). CAS are also used for species-specific ecological studies (Tupper & Cook, 2008) and to assess the effectiveness of habitat restoration efforts (Stevens et al., 2002). Environmental factors such as rainfall, air temperature, water temperature (Pellet & Schmidt, 2005; Gooch et al., 2006), and time of year all interact to affect the timing and intensity of anuran calling activity (see Saenz et al., 2006) and consequently a researcher's chances of detecting anuran calls (Shirose et al., 1997).

These environmental factors vary across latitudes and even regionally within latitudes (e.g., from Rhode Island to Cape Cod, Massachusetts); as a result, so does anuran calling activity (Berven, 1982; de Solla et al., 2006; Tupper et al., 2007; Cook et al., 2011). Therefore, implementing a precise and efficient localized, long-term monitoring program can be challenging because it is most effective to design programs around peak calling activities, i.e., when chances of detecting vocalizations are highest (Crouch & Paton, 2002; Cook et al., 2011).

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Although studies have addressed anuran monitoring in southern New England (Crouch & Paton, 2002; Tupper et al., 2007; Cook et al., 2011) and the south Atlantic states (see Bridges & Dorcas, 2000; Dorcas et al., 2009; Steelman & Dorcas, 2010), to our knowledge systematically collected, non-anecdotal data are limited for the mid-Atlantic states (but see Weir et al., 2005; Brander et al., 2007). Though various works describe anuran breeding activities (Lee, 1973; Mitchell, 1979; Ernst et al., 1997) in northern Virginia and adjacent areas, to the best of our knowledge none have quantitatively approached this issue for the purpose of optimizing long-term monitoring programs. We present data collected from two seasons of CAS sampling at Huntley Meadows Park in Fairfax County, Virginia, that can be used to help guide implementation of long-term anuran monitoring programs in the mid-Atlantic states. Our goals were to (1) identify the most appropriate times of year and night (peak detection periods) and corresponding ambient temperatures to sample for anuran species with CAS; (2) to identify the number of sampling occasions needed during a species' peak detection period to achieve a 90% probability of at least one detection at an occupied site and (3) to calculate the number of wetlands needed to sample to estimate occupancy with a standard error (SE) of 0.10 (Cook et al., 2011).

MATERIALS AND METHODS

Study Area

Huntley Meadows Park (Fairfax County, Virginia; 38°45′20.95″N; 77°06′29.26″W) is a 577 ha park that is predominantly surrounded by densely populated suburban developments, except for a fragmented green corridor on the southeast side of the park (Fig. 1). The majority of the park (the central wetland) is within wet lowland formed by an early meander of the Potomac River. The central wetland is hydrologically connected to the majority of wetlands within the park. However, the vegetational communities existing in the different regions of the park range from early-successional wetlands to later-successional hardwood swamps. Consequently, the abiotic features of these wetlands are also quite different. Water can be tannin-lignin rich, cool, and acidic, to clearer, warm, and more neutral (DL, unpubl. data). All park wetlands are freshwater, and together with the biotic characteristics of the environment, form a biodiverse and important ecosystem in Fairfax County (http://www.fairfaxcounty.gov/parks/huntley/).

Site Selection

We used a stratified-random scheme to select 15 wetlands for CAS sampling. Using Google Earth version 6 (http://www.google.com/earth/index.html) at an 'eye altitude' of 4.19 km, we created a grid consisting of 122 220 m x 282 m cells over high-resolution satellite imagery of Huntley Meadows Park. We assigned each cell into one of our strata (northern, central, and southern regions of the park) and randomly selected five cells (> 200 m apart) in each region. We then sampled the wetland nearest the center of each selected cell using CAS methodology. We assigned each wetland to one of three calling survey routes (one route per aforementioned strata), each consisting of five wetlands (Fig 1). Selected study wetlands ranged from short-hydroperiod, fishless ephemeral wetlands, to permanently inundated wetlands containing fish.

Data Collection

We recorded up to four ordinal calling index values (0-3) following North American Amphibian Monitoring Program (NAAMP) guidelines (Weir & Mossman, 2005) to quantify anuran calling activity where 0 = no calls, 1 = calling but no overlap between calls, 2 = intermediate overlap and 3 = continuously overlapping calls. Sites were typically sampled between 30-min after sunset and 2400 h (Weir & Mossman, 2005). The order in which sites were sampled was rotated to avoid temporal sampling biases. Because it is well known that detection probability is greatly affected by air and surface water temperatures (Gooch et al., 2006;

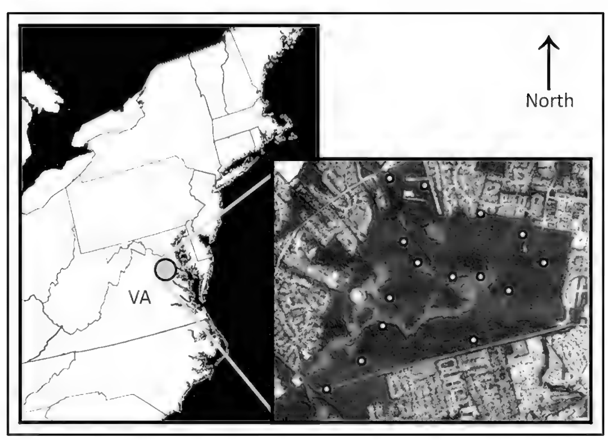


Fig. 1. Huntley Meadows Park, Fairfax County, Virginia (38°45′20.95″N; 77°06′29.26″W). Black and white circles in enlarged area represent calling survey points.

Steelman & Dorcas, 2010; Cook et al., 2011) and that both air and water temperatures are good predictors of anuran body temperatures (Fouquette, 1980), we recorded ambient temperatures during each sampling event. We placed a thermometer approximately 1.5 m above the ground for 5 min to measure air temperature (°) and we placed a thermometer between 1.5 and 3 cm beneath the water's surface for 5 min to measure surface water temperature (˚C). In accordance with NAAMP guidelines (Weir & Mossman, 2005), we also recorded sky conditions, noise disturbance, and wind codes (on the Beaufort scale).

Nightly and Seasonal Calling Chronology

We were interested in determining when, within established NAAMP CAS sampling guidelines (ca. 30 min after sunset to ca. 2400 h), detected species were encountered while chorusing so that future sampling could accommodate known peak periods of nightly activity. We accomplished this by calculating mean, 95% confidence interval (CI), and range of time (minutes) after sunset that chorusing and non-chorusing events occurred for each species. We examined differences in timing of calling between chorusing (calling index ≥ 1) and non-chorusing (calling index = 0) events with 2-sample t-tests (Zar, 1999). To identify peaks in calling activity and describe seasonal calling chronology, we grouped surveys by sampling week (a 7-day interval starting from the first survey) and calculated a naïve detection probability (p; number of times a species was detected/number of samples per week) per species, per sampling week. We defined peaks as any sampling week that yielded a $p \geq 0.90$*maximum p). We used a one-way analysis of variance (ANOVA) and Tukey's post-hoc multiple comparison (Zar, 1999) to identify interspecific differences in detection probabilities (data square-root arc sin transformed). Residual plots were used to assess equality of variances and normality. Interspecific differences in calling chronology (days to first detection) were assessed with a Pearsons chi-square statistic (Zar, 1999).

Ambient Temperature

In multivariate analyses, Cook et al. (2011) found that surface water temperature had a larger effect on anuran calling activity than air temperature. Thus, we chose to focus our ambient temperature analyses on surface water temperature. We examined differences in mean surface water temperatures (grouped by sampling week) between chorusing and non-chorusing events with paired samples t-tests or one-sample Wilcoxon signed-rank tests. Paired-samples t-tests were used to examine differences in annual rainfall and temperature. Normality was assessed with normal probability plots and Kolmogorov-Smirnov tests and equality of variances was assessed with Levene's test for equality of variance (Zar, 1999).

Determining a Sampling Regime

MacKenzie & Royle (2005) define an "optimal" sampling scheme as one that provides an 85% to 95% probability of confirming that a target species occupies a site. Thus, for each species, we estimated the number of sampling occasions per site needed to achieve 90% probability of detecting the target species (see Cook et al., 2011) at least once during its peak calling period in a given year at occupied sites using the formula $p^* = 1 - (1 - p)^k$, where p = maximum naïve detection probability and k = number of sampling occasions/site (adapted from MacKenzie & Royle, 2005). We calculated the number of wetlands necessary to sample to estimate future occupancy (Ψ) rates ($\alpha = 0.10$) with equation 6.3 in MacKenzie et al. (2006).

Microsoft Excel 2007 was used to create figures, calculate equations presented in Mackenzie et al. (2006), and compute some descriptive statistics (standard deviation [SD], 95% CI). Additional descriptive statistics and hypothesis tests were completed in Minitab version 14 (www.minitab.com). Maps were created with Google Earth version 6 and Microsoft PowerPoint 2007. Because anuran breeding behavior can be highly variable between years (Bishop et al., 1997), we pooled data from 2009 and 2010 to more accurately describe patterns in anuran calling chronology.

RESULTS

Descriptive Statistics, Calling Chronology, and Sampling Windows

We conducted a total of 775 calling surveys (CAS); 390 in 2009 and 385 in 2010. A mean of 12.2 (SD = 6.1) and 10.7 (SD = 4.6) CAS per sampling week were conducted in 2009 and 2010, respectively. The annual mean temperatures for 2009 and 2010 were 14.3°C (SD = 9.41) and 15.6°C (SD = 10.4), respectively. Annual mean rainfall was 0.37 cm in 2009 (SD = 0.76) and 0.27 cm in 2010 (SD = 0.88). We found no significant differences in monthly mean rainfall and temperature between years (rainfall $t = -2.05$, $P > 0.05$; temperature $t = 1.23$, $P > 0.05$).

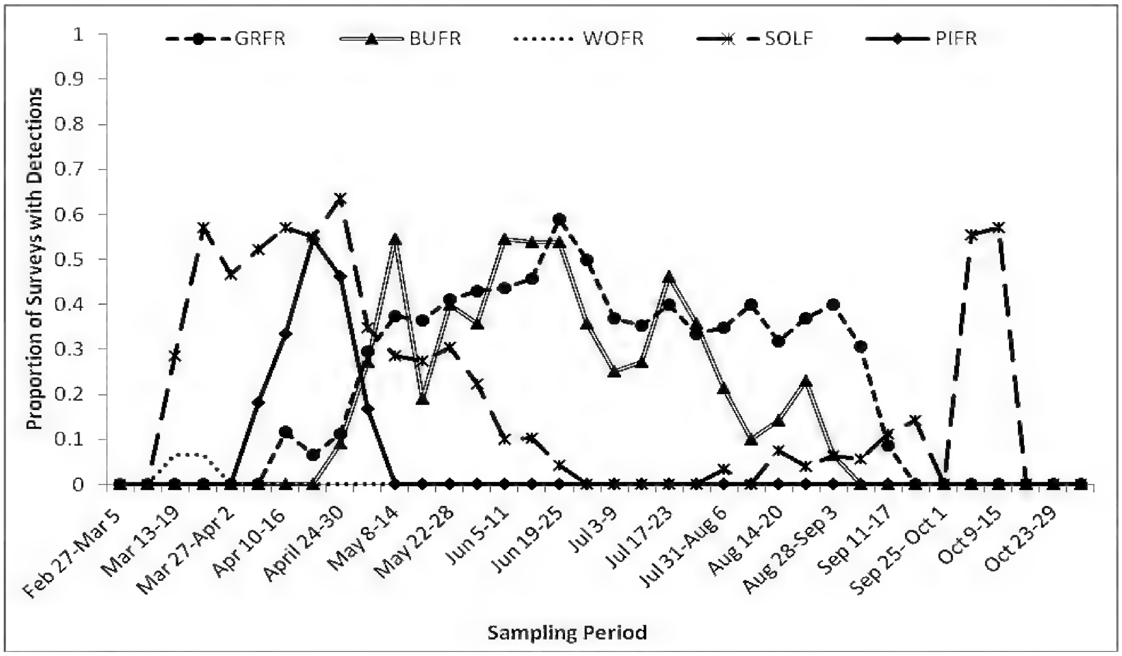
Ten species were identified (Table 1), but Fowler's Toad (*Anaxyrus fowleri*) and Wood Frog (*Lithobates*

Table 1. Occupancy data (detections[1]; non-detections[-]) for anurans identified with CAS at Huntley Meadows Park. % Total Species = % of total species present at a given site; % Sites Occupied = naïve occupancy calculations (# of sites with detections/total # of sites sampled), AMTO = American Toad (*Anaxyrus americanus*), FOTO = Fowler's Toad (*Bufo fowleri*), CGTF = Cope's Gray Treefrog (*Hyla chrysoscelis*), GRTF = Green Treefrog (*Hyla cinerea*), BUFR = American Bullfrog (*Lithobates catesbeianus*), GRFR = Green Frog (*Lithobates clamitans*), PIFR = Pickerel Frog (*Lithobates palustris*), SLFR Southern Leopard Frog (*Lithobates sphenocephalus*), WOFR = Wood Frog (*Lithobates sylvaticus*), and SPPE = Spring Peeper (*Pseudacris crucifer*).

Sites	AMTO	FOTO	CGTF	GRTF	BUFR	GRFR	PIFR	SLFR	WOFR	SPPE	% Total Species
AUG	1	1	1	-	-	1	1	1	1	1	80
ARMY	-	-	-	-	-	-	-	-	-	1	10
BCWL	1	-	1	1	1	1	1	1	-	1	80
CG	1	-	1	-	-	1	-	1	-	1	50
DCGL	-	-	-	-	-	-	-	1	-	1	20
DITCH	-	-	-	-	-	1	-	1	-	1	30
DRP	-	-	1	1	1	1	1	1	-	1	70
MDW	1	-	1	-	-	1	-	1	-	1	50
MSL	-	-	-	-	-	-	-	1	-	1	20
NCWL	1	-	1	1	1	1	1	1	-	1	80
NSL	-	-	1	-	-	-	-	1	-	-	20
PT	1	-	1	-	1	1	1	1	-	1	70
PWL	1	1	1	-	-	1	1	1	-	1	70
SCWL	1	1	1	1	1	1	1	1	-	1	90
SSL	1	-	1	-	-	1	-	1	-	1	50
% Sites Occupied	60	20	73	27	33	73	47	93	7	93	-

sylvaticus) were detected on <4 sampling occasions so data are not meaningful. Full choruses (i.e., calling index values = 3) were detected in all species except Pickerel Frogs (*L. palustris*). Chorusing events for Green Treefrog (*Hyla cinerea*) tended to occur slightly nearer sunset (mean = 120.9 [95% CI = 17.2] min after sunset) than non-chorusing events (mean = 149.4 [95% CI = 23.5] min after sunset; t = 1.96, df = 101; P = 0.05). Diel differences were not detected in other species. Seasonal calling chronologies were described for all species, and the number of days to first detection differed significantly between species (X^2= 62.5; df = 9; P < 0.05; Fig. 2), with Spring Peeper and American Bullfrog (*L. catesbeianus*, hereafter Bullfrog) being the first and last species, respectively, to commence calling (Fig. 2). We found interspecific differences in detection probabilities ($F = 3.57_{7,\ 111}$; $P < 0.05$) with two homogenous subgroups identified. Subgroup A (Pickerel Frog and American Toad [*A. americanus*]) had lower naïve detection probabilities than subgroup B (Green Frog [*L. clamitans*], Bullfrog, Green Treefrog, Spring Peeper [*Pseudacris crucifer*], Southern Leopard Frog [*L. sphenocephalus*], and Cope's Gray Treefrog [*H. chrysoscelis*]). Peak activity periods also varied depending on the species. We identified two sampling windows (ca. 27 March-17 April [window 1] and ca. 15 May-16 July [window 2]) appropriate for long-term monitoring. Peaks for American Toad, Pickerel Frog, Southern Leopard Frog, and Spring Peeper occurred within sampling window 1 and peaks for Cope's Gray Treefrog, Green Treefrog, Bullfrog, and Green Frog occurred within sampling window 2 (Table 2).

(a) True Frogs



(b) Toads, Chorus Frogs, and Treefrogs

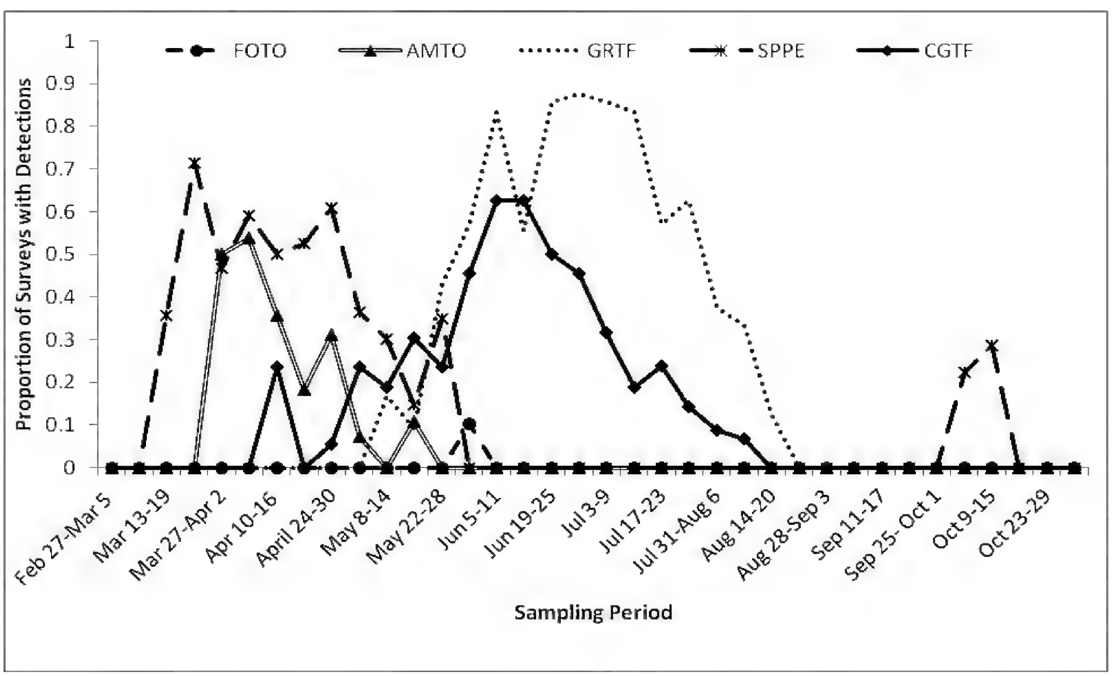


Fig. 2. Calling chronology for true frogs (a) and toads, chorus frogs, and treefrogs (b) detected at Huntley Meadows Park. Data are pooled from 2009 and 2010.

Table 2. Dates of calling activity and peak calling periods for anurans detected with CAS. We were unable to determine peak calling periods for Fowler's Toad and Wood Frog because of too little data.

Species	Dates of Calling Activity	Peak Calling Periods
American Toad	3/23-5/8	4/10-4/30
Fowler's Toad	5/23-5/27	---
Cope's Gray Treefrog	4/5-7/31	5/29-6/11
Green Treefrog	5/6-8/10	5/20-5/26; 6/12-6/25
American Bullfrog	4/22-8/23	5/1-5/7; 5/29-6/18; 7/10-7/16
Green Frog	4/5-9/5	6/12-6/25
Pickerel Frog	4/1-4/27	4/10-4/23
Southern Leopard Frog	3/9-6/12; 8/8-10/8	4/10-4/23; 9/25-10/8
Wood Frog	3/11-3/19	---
Spring Peeper	3/7-5/21	3/13-3/19; 3/27-4/2; 4/10-4/23

Ambient Temperature and Sampling Regime

Chorusing events for all species except pickerel, southern leopard, and gray treefrogs tended to occur when surface water temperatures were significantly warmer than did non-chorusing events (within the range of breeding activity). The minimum threshold temperatures required for vocalization increased as the season progressed (Table 3). For example, during the first week of May we detected Bullfrog when surface water temperatures averaged 16.9°C (SD = 4.07). In mid-July, surface water temperatures were considerably warmer on nights when this species was not heard chorusing (mean = 21.3°C; SD = 0.35; Fig. 3). Choruses during this time period (i.e., July 17-23) occurred at an average temperature of 23.8°C (SD = 2.32). Similar patterns were seen in all other species.

The optimal number of sampling occasions needed to detect each species (per site with a 90% probability of detection) during peak calling periods ranged from 2 to 24 (mean = 7.9; SD = 10.8), with ≤5 sampling occasions necessary for 8 of the 10 species. The number of wetlands needed to survey to estimate Ψ (with SE = 0.10) ranged from 7–42 (mean = 24.5; SD = 10.5; Table 4).

DISCUSSION

Applications and Future Monitoring

Many studies describe various aspects of vocalization in species detected in this study (e.g., Wright, 1914; Wright & Wright, 1949; Wiewandt, 1969; Garton & Brandon, 1975; Gerhardt & Klump, 1988; Given, 2002) and aspects of anuran breeding phenology have been documented since the early 1900s (e.g., Wright, 1914; Harper, 1928; Babcock & Hoops, 1940). This study yields specific information important for long-term anuran monitoring in the northern mid-Atlantic States. Two sampling windows are needed to successfully monitor the eight species (ca. 27 March-17 April [window 1] and ca. 15 May-16 July [window 2]) and we estimate that a total of five sampling occasions during these windows are necessary to successfully detect vocalizations. Because chorusing events for Green Treefrog tended to occur nearer to sunset, it is essential that the order in which sites are sampled be rotated. Sites that are consistently sampled later than others may result in artificially low detection probabilities and inaccurate occupancy rates.

We provide a range of minimum temperatures during which vocalizations were documented and found that the threshold temperatures for vocalization tend to increase as the season (within a species' range of calling activity) progressively increases even if lower temperatures, which supported calling in weeks prior, occur. Temperature must be considered in conjunction with time of year (Table 3).

True Frogs (Family Ranidae)

As reported by Babcock & Hoops (1940), Emlen (1976), Klemens (1993), Mohr & Dorcas (1999), Crouch & Paton (2002), Weir et al. (2005), and Cook et al. (2011), our data show that Bullfrog has a somewhat protracted calling season. Detection probabilities are highest from mid-May to the end of June, with a central "peak" occurring between 29 May and 11 June. Our data differ from studies conducted in southern New England where peaks are considerably later, occurring

Table 3. Minimum surface water temperatures recorded during detection events throughout each species' calling season. * = that surface water temperature had a significant effect on calling. Significance was determined with a paired samples t-test or Wilcoxon signed rank test (α= 0.05). Contact corresponding author for *P*-values and test statistics.

Week Interval	AMTO*	FOTO	CGTF*	GRTF	BUFR*	GRFR*	PIFR	WOFR	SLFR	SPPE*
Feb 27-Mar 5	-	-	-	-	-	-	-	-	-	-
Mar 6-12	-	-	-	-	-	-	-	-	-	-
Mar 13-19	-	-	-	-	-	-	-	14.0	10.0	10.0
Mar 20-26	-	-	-	-	-	-	-	12.0	9.5	9.0
Mar 27-Apr 2	9.2	-	-	-	-	-	-	-	6.7	5.6
Apr 3-9	11.8	-	-	-	-	-	15.5	-	11.7	11.7
Apr 10-16	13.9	-	17.8	-	-	19.5	6.1	-	6.1	10.6
Apr 17-23	12.8	-	-	-	-	16.0	12.2	-	10.0	10.0
April 24-30	13.9	-	19.0	-	17.0	15.3	15.0	-	11.7	11.7
May 1-7	16.7	-	13.0	-	13.0	13.0	15.0	-	13.0	13.0
May 8-14	-	-	17.8	20.5	13.9	13.9	-	-	13.9	15.3
May 15-21	16.1	-	15.0	18.3	16.0	14.8	-	-	13.5	15.0
May 22-28	-	-	18.5	15.0	15.0	15.0	-	-	12.2	14.4
May 29-Jun 4	-	18.8	17.2	20.5	20.3	13.3	-	-	13.3	-
Jun 5-11	-	-	18.9	20.0	18.9	18.9	-	-	20.0	-
Jun 12-18	-	-	18.0	20.0	20.0	18.0	-	-	18.0	-
Jun 19-25	-	-	21.0	22.5	22.5	21.5	-	-	23.5	-
Jun 26-Jul 2	-	-	22.5	22.0	22.0	22.0	-	-	-	-
Jul 3-9	-	-	23.5	23.5	23.5	23.5	-	-	-	-
Jul 10-16	-	-	21.0	21.0	21.0	21.0	-	-	-	-
Jul 17-23	-	-	21.5	21.5	20.5	20.5	-	-	-	-
Jul 24-30	-	-	23.5	25.8	23.0	23.0	-	-	-	-
Jul 31-Aug 6	-	-	24.0	24.0	24.0	24.0	-	-	24.0	-
Aug 7-13	-	-	25.0	23.8	25.0	23.8	-	-	-	-
Aug 14-20	-	-	-	26.3	24.0	23.0	-	-	24.0	-
Aug 21-27	-	-	-	-	23.3	23.0	-	-	23.3	-
Aug 28-Sep 3	-	-	-	-	25.0	22.8	-	-	24.5	-
Sep 4-10	-	-	-	-	-	18.5	-	-	18.5	-
Sep 11-17	-	-	-	-	-	19.0	-	-	20.0	-
Sep 18-24	-	-	-	-	-	-	-	-	18.5	-
Sep 25- Oct 1	-	-	-	-	-	-	-	-	-	-
Oct 2-8	-	-	-	-	-	-	-	-	15.8	18.3
Oct 9-15	-	-	-	-	-	-	-	-	11.0	12.8
Oct 16-22	-	-	-	-	-	-	-	-	-	-
Oct 23-29	-	-	-	-	-	-	-	-	-	-
Oct 30-Nov 6	-	-	-	-	-	-	-	-	-	-

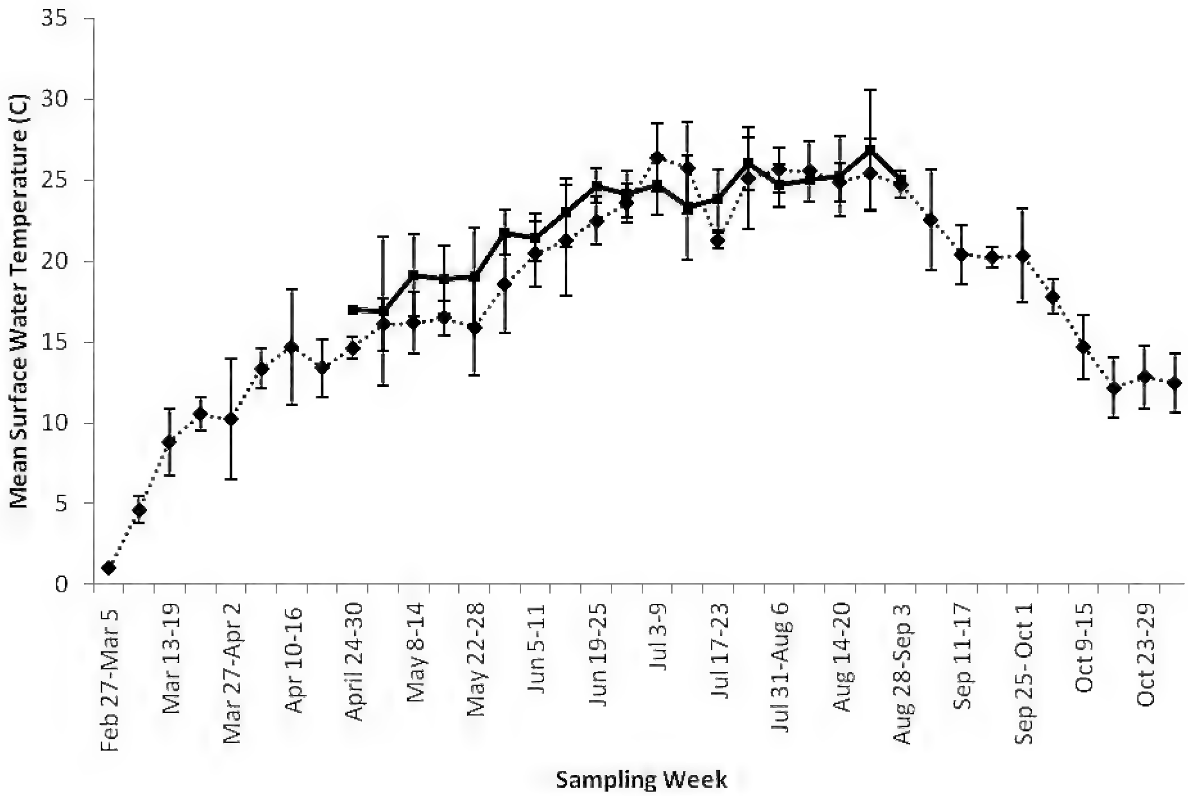


Fig. 3. Mean surface water temperatures recorded throughout the American Bullfrog calling season (solid line = detections, dotted line = non-detection, whiskers = 95% CI). Surveys that resulted in detections yielded warmer surface temperatures than surveys resulting in non-detections. The non-detections recorded during cooler temperatures later in the season occurred at warmer temperatures than calling events recorded earlier in the season. This pattern indicates changing threshold temperatures for calling throughout the season. This trend was similar for all species detected. Contact corresponding author for additional figures.

Table 4. Power analysis and sites needed to estimate Ψ. Ψ = occupancy rates, Max Naïve p = maximum naïve detection probabilities. The next two columns from left to right are: [1]the number of samples needed to detect a given species at sites where present (with 90% probability of detection) and [2]the number of sites needed to estimate site occupancy rates with SE = 0.10. * = too few detections, data should be interpreted cautiously.

Species	Ψ	Max Naïve p	Sampling Occasions[1]	Wetlands[2]
American Toad	0.600	0.538	3	35
Fowler's Toad*	0.200	0.103	21	19
Cope's Gray Treefrog	0.733	0.313	5	42
Green Treefrog	0.267	0.857	2	20
American Bullfrog	0.333	0.545	3	28
Green Frog	0.733	0.588	3	28
Pickerel Frog	0.467	0.545	3	33
Southern Leopard Frog	0.933	0.636	3	13
Wood Frog*	0.067	0.067	34	7
Spring Peeper	0.933	0.714	2	21

throughout July in Rhode Island (Crouch & Paton, 2002) and Massachusetts (Cook et al., 2011). Our recorded intra-seasonal range of vocalization for this species is similar to anecdotal accounts of vocalization in New York (Wright & Wright, 1949; Bury & Whelan, 1984) and Connecticut (Klemens, 1993). Our Bullfrog data more closely resemble patterns described by Weir et al. (2005), where an estimated seasonal peak occurred at ca. 31 May throughout eastern and central Maryland. Ernst et al. (1997) report calling beginning in late April or early May in northern Virginia. Though our earliest identified vocalization of Bullfrog was 22 April in this study, we have observed vocalizations (not full choruses) in March at the Smithsonian Environmental Research Center, Edgewater, Maryland and in Arlington County, Virginia. All accounts of Bullfrog calling from the southeastern United States (the Carolinas and Georgia) in the 1920s and 1930s by Harper (1934) occurred within, or two weeks prior to, our observed range of activity.

Mohr & Dorcas (1999) and Bridges & Dorcas (2000) indicate that peak calling activity for Bullfrog occurs between ca. 0400 h and 0600 h, well after established NAAMP protocol guidelines. However, like Cook et al. (2011), we found that NAAMP guidelines seem appropriate for detection of Bullfrog, as we detected this species on 75/105 sampling events within the range of its calling activity.

The Green Frog breeding season also appeared protracted (which appears typical of this species, see Wells, 1977; Klemens, 1993; Ernst et al., 1997; Mohr & Dorcas, 1999; Crouch & Paton, 2002; Cook et al., 2011). Peak periods of activity for Green Frog on Lower Cape Cod, Massachusetts (ca. 30 June – 26 July) and in Washington County, Rhode Island (Crouch & Paton, 2002; ca. 20-24 July) were expectedly later than in our study (between 12 and 25 June) and in Maryland ([ca. 31 May; Weir et al., 2005]; Ernst et al., 1997). In Connecticut, Klemens (1993) reported calling throughout our documented range of calling for this species. In areas adjacent to Klemens' (1993) study sites, Babbitt (1937) and Wright & Wright (1949) indicated that the onset of chorusing occurs from mid to late May, which is approximately one month later than documented in northern Virginia and approximately two months later than documented in Texas (Saenz et al., 2006). Interestingly, the earliest record of Green Frog vocalization by Harper (1934) from the early 1930s in Okefinokee Swamp, Georgia occurred six days later (11 April 1933) than in our study.

Using an automated recording system, Cook et al. (2011) determined that peak diel activity for Green Frog occurred in Massachusetts at ca. 2400 h, whereas Mohr & Dorcas (1999), also employing an automated recording system, reported that it occurred at ca. 0400 h in South Carolina. The actual peak diel calling activity for Green Frog in the mid-Atlantic likely occurs before 0400 h and after 2400 h, well outside the NAAMP guidelines. This suggestion is based on variation in peak calling times associated with latitudinal differences in Cook et al. (2011) and Mohr & Dorcas (1999). Nevertheless, in our study, Green Frog appears to have called frequently enough during NAAMP guidelines to ensure detections (we detected Green Frog on 155/295 of sampling events during the range of its calling activity).

Southern Leopard Frog is known as a spring and fall breeder (Caldwell, 1986; Gibbons & Semlitsch, 1991; Roble, 2003; Gibson & Sattler, 2010). However, Bridges & Dorcas (2000) documented consistent calling activity throughout July 1997 in South Carolina. We documented consistent calling activity between 9 March and 12 June, and then again between 8 August and 8 October. No calling was detected in July 2009 or 2010. Weir et al. (2005) also defined a seasonal calling chronology for this species, but their estimated chronology contains only a single peak on ca. 31 May, which is one month later than our first peak (10-23 April) and does not account for a fall peak. This variation is surprising considering the close proximity of our respective study sites (both 41° N latitude), indicating the importance of increasing interannual sampling to ensure accurate description of anuran calling chronology.

In Maryland, Lee (1973) found that Southern Leopard Frog calls began in February and ended in June. His findings and anecdotal observations by Ernst et al. (1997) appear consistent with our early peak of Southern Leopard Frog vocalization, but also do not account for late summer/early fall vocalizations. The onset of Southern Leopard Frog calling in North Carolina occurred later than in our study (20 and 21 February, Todd et al. [2003]; Steelman & Dorcas [2010]). Though it was known then that calling occurred in months prior, the earliest date of Southern Leopard Frog calls recorded in North Carolina in the early 1930s occurred on 2 April, which seems late for the region (Harper, 1935).

Harper (1935) indicated that the strongest choruses of Southern Leopard Frog occur between midnight and dawn. He attributed this diel pattern to a preference for calling when nightly temperatures drop. He suggested that, "the affinities of this species may be boreal rather than austral for its closest relative, *Rana pipiens*, is one of the most northerly ranging of American frogs." This hypothesis provides an important perspective given climate change and its suggested effect on anuran calling chronology (Gibbs & Breisch, 2001): how

would climactic warming affect this boreal species? See Bridges & Dorcas (2000), Todd et al. (2003), and Steelman & Dorcas (2010) for more data on diel chronology in this species.

Activity for Pickerel Frog was abbreviated in comparison to other ranids detected in our study. Our results are comparable to those of Weir et al. (2005) and concur with observations made by Ernst et al. (1997). Though we did not confirm Pickerel Frog vocalizations in March (as did Ernst et al. [1997]), we have anecdotally heard calls in March in northern Virginia and Maryland. In southern New England, peaks occurred later in the season, within the first three weeks of May (Crouch & Paton, 2002; Cook et al., 2011). Onset of calling occurs in late February in North Carolina (Todd et al., 2003) and as early as January in Texas (Sanez et al., 2006). Todd et al. (2003) reported a diel peak within NAAMP guidelines (at ca. 2100 h), with vocalizations continuing into the early morning hours.

American Toad (Family Bufonidae)

American Toad also had a short (and discontinuous) calling season which can complicate monitoring. Our results are similar to Weir et al. (2005) and consistent with observations by Ernst et al. (1997), but as expected, are somewhat earlier than in Rhode Island (peak between 15-21 May; Crouch & Paton, 2002), Connecticut and New York (late April and May; Wright & Wright, 1949; Klemens, 1993). American Toad was heard vocalizing on 2 June 1934 in Georgia (elevations of 947 and 1353 m) and on 19 June 1934 (elevation 426 m) in Tennessee (ambient temp was ca. 14°C; Harper, 1935), which is surprisingly late considering the southern latitude.

Chorus Frogs and Treefrogs (Family Hylidae)

Spring Peeper yielded high detection probabilities (similar to Crouch & Paton [2002], Weir et al. [2005], and Cook et al. [2011]) and displayed a relatively continuous calling season. This continuity is advantageous as its peak calling period is relatively wide, providing a large sampling window. Onset of Spring Peeper calling began considerably earlier in this study (7 March, which is later than reported by Ernst et al., [1997]) than in New England (Crouch & Paton, 2002; Cook et al., 2011), but was much later than in the Carolinas (Martof et al., 1980; Steelman & Dorcas, 2010) and Texas (Saenz et al., 2006), where calling was recorded as early as January.

Spring Peeper calling chronology in New York (Wright & Wright, 1949), Connecticut (Klemens, 1993), Massachusetts (Cook et al., 2011), and Rhode Island (Crouch & Paton 2002) appears more similar to patterns seen in Maryland and Virginia (Mitchell, 1979) than those of the coastal southeastern United States where chorusing can be heard from October to March (Martof et al., 1980). Surprisingly, all accounts of late winter/spring calling from Florida, Georgia, Kentucky, and Tennessee in 1934 (Harper, 1935) occurred within or later than winter/spring Spring Peeper activity in this study.

Green Treefrog had approximately one month of frequent and continuous calling activity with a peak in late May and in mid to late June. Our intraseasonal data are consistent with Martof et al. (1980) and Ernst et al. (1997). Our diel data concur with Mohr & Dorcas (1999) and with Garton & Brandon (1975), who indicate that chorusing declines sharply between 2250 h and 2400 h.

Our estimated peak calling range for Cope's Gray Treefrog (29 May-11 June) is consistent with other findings in the region (Ernst et al., 1997; Weir et al., 2005). Our data also agree with Martof et al. (1980), who indicate that calling activity in Virginia and the Carolinas for "gray tree frogs" (combining observations on the sibling species *H. chrysoscelis* and *H. versicolor*) occurs from May to August. Harper (1935) described gray treefrog calling in the southeastern United States but also did not distinguish between these two species. Interestingly, all but one of his observations from the southeast (2 April 1933, North Carolina) occurred within our range of activity (4/5-7/31).

CONCLUSIONS

Though our results are similar to observations and studies from Maryland and Virginia, we identified data necessary for localized long-term anuran monitoring programs. Monitoring anuran breeding activity is important because shifting calling chronologies is a possible indication of biotic response to climate change (Gibbs & Breisch, 2001). Calls of most species identified in this study were also observed some 80 years ago in the Southeast by Harper (1935). It appears that onset of calling for species in both studies are nearly identical, which is surprising. We expected that initiation of calling in the Southeast would be considerably earlier than in the mid-Atlantic (given the typically warmer southern climates). We do not know if Harper's (1935) study began later in the season, if the onset of calling in the Southeast is typical in regions where data were collected, or if results of our and other recent studies indicate climactic warming (see Gibbs & Breisch, 2001).

With the exception of Harper's (1935) observations, species detected at Huntley Meadows Park that were also detected in study areas farther north initiate calling earlier than in the north, but later than in the south. The sequential order in which species vocalized was remarkably similar to other regions of the United States and Canada (Klemens, 1993; Bishop et al., 1997; Lepage et al., 1997; Brodman & Kilmurray, 1998; Mossman et al., 1998; Varhegyi et al., 1998; Crouch & Paton, 2002; Saenz et al., 2006; Cook et al., 2011) and supports what naturalists have observed, albeit less quantitatively, for decades.

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Survey and Assessment of Man-made Structures Used by Rafinesque's Big-eared Bats (*Corynorhinus rafinesquii*) in Southeastern Virginia

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ABSTRACT

The distribution and abundance of Rafinesque's Big-eared Bat, a state-endangered species in Virginia, were investigated in 2008 by surveying previously documented and undocumented man-made structures. Of the 94 previously documented sites or structures inhabited by this species, 23 were confirmed to be in good status and 15 of these had bats present. Fourteen structures had been destroyed since 2002, 29 structures were known to have been destroyed prior to 2002, the status of seven structures was deemed vulnerable and the fate of 21 sites or structures was unknown,. Four active nursery colonies, each containing 30 to 50 females and their young, and 11 solitary roosts were documented during this study. Approximately 200 individuals were observed, mostly in Southampton and Sussex counties and the City of Virginia Beach. The overall population status in Virginia is unknown. Continued publicity and education are needed to enlist landowner cooperation and to locate other bat roosts.

Key words: Rafinesque's Big-eared Bat, distribution, Virginia.

INTRODUCTION

Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii*) is classified as a state endangered species (as *C. rafinesquii macrotis*, the Eastern Big-eared Bat) in the Commonwealth of Virginia (VDGIF, 2005). The Virginia Department of Game and Inland Fisheries' (VDGIF) Comprehensive Wildlife Conservation Strategy ranks *C. rafinesquii* as a Tier I Species of Greatest Conservation Need (VDGIF, 2005). The Virginia Endangered Species Recovery Plan for the Eastern Big-Eared Bat outlines many recovery needs and strategies for this species (Schwab et al., 1990). The first goal of the Recovery Plan is to determine the distribution of *C. rafinesquii* in Virginia by searching man-made and natural roost sites for day-roosting

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adults. In Virginia, this nocturnal species has been found roosting inside the hollows of Black Gum (*Nyssa sylvatica*) (Terwilliger Consulting, Inc., 2001), Water Tupelo (*Nyssa aquatica*) (Hobson, 1998), and Bald Cypress (*Taxodium distichum*) (Handley & Schwab 1991; Terwilliger Consulting, Inc., 2001) trees. However, most *C. rafinesquii* records in Virginia are from man-made, abandoned structures (VAFWIS, 2008). During the summer, females and their young form groups known as maternity or nursery colonies, but no nursery colonies have been discovered in tree roosts in Virginia (Carpenter, 2008). The second goal of the Recovery Plan is to identify essential habitat such as nursery colonies, hibernacula, and roosts of solitary bats. Once these sites have been identified, goals three and four recommend investigations into their natural history and developing a plan to monitor population trends (Schwab et al., 1990). The fifth goal of the Recovery Plan is to protect roost sites and other habitat from adverse modifications by enlisting the assistance of landowners.

There are only five records of *C. rafinesquii* in Virginia from 1897 to 1991 (Handley 1979; Handley & Schwab, 1991). Surveys by VDGIF began in 1993, with the most comprehensive study conducted in 1997 and 1998 by Brian Saunders and Donald Schwab. They reported 81 abandoned buildings in the counties of Greensville, Hanover, New Kent, Southampton, and Sussex, and the cities of Chesapeake and Suffolk that served as roost sites for Rafinesque's Big-eared Bats, including 12 nursery colonies (Garrett, 2001). The sum of the maximum number of bats observed at each site during that study was 471. Structure surveys in 2001 revealed that half of the previously documented nursery colony sites had been abandoned or destroyed (Garrett, 2001). In 2000, a radio-telemetry study tracked eight *C. rafinesquii* individuals to roosts in the vicinity of First Landing State Park (Terwilliger Consulting, Inc. 2001). In 2006, new sites were documented in the City of Suffolk and Isle of Wight County and the first hibernaculum was documented in Virginia (Carpenter, 2008). The present study was undertaken to document the continued presence and viability of *C. rafinesquii* in southeastern Virginia.

MATERIALS AND METHODS

To address the first goal of the Recovery Plan, surveys of potential man-made roost sites were conducted during 2008 by revisiting previously documented sites and road cruising for additional structures. Buildings were visually surveyed during the day from June to September 2008. Accessible rooms, closets, and attics of each structure were searched for bats, guano or other signs of use. Following the protocol from previous surveys, a management profile was established for each structure inhabited by *C. rafinesquii*, containing data on the number and behavior of bats, GPS location and address, and building characteristics (e.g., number of rooms, stories and type of roof). Newly discovered structures that looked suitable but did not have bats were recorded as null sites. Landowner contacts were updated by phone interviews or written correspondence to acquire permission to access structures and discuss building status. The status of previously occupied structures was assessed as 'good,' 'vulnerable,' 'destroyed,' or 'unknown.' Unknown status was assigned to a structure if permission from the landowner was not granted or the structure could not be located. Additional records of *C. rafinesquii* were also entered into the Virginia Fish and Wildlife Information System (VAFWIS) database. Natural roost sites (i.e., tree hollows) were not included in this survey due to inaccessibility.

RESULTS AND DISCUSSION

From 1993 to 2008, there were 94 records of *C. rafinesquii* in 10 counties and municipalities in southeastern Virginia, with most observations obtained in Southhampton County (Table 1). We documented a total of 15 structures inhabited by *C. rafinesquii*, including 11 solitary roosts and four nursery colonies (Table 1). The structures were abandoned two-story houses where the bats utilized attics, interior hallways, and closets. A barn, an abandoned one-room schoolhouse, an old country store, and two concrete bunkers also were used. Solitary roosts in Virginia were also observed under a bridge (Carpenter 2008) and inside a large hollow tree (Hobson, 1998). The sum of the maximum number of bats observed at each site during this study was 165. We confirmed the destruction of 14 structures previously known to be used by *C. rafinesquii*. Landowners cited natural decomposition, hurricanes and storms, property development, and property upkeep as reasons for collapsing or destroyed structures.

To monitor population trends, four previously known nursery colonies were revisited in Southampton and Sussex counties and the City of Virginia Beach. In 2008, each of these colonies consisted of 30 to 50 bats (Table 2), indicating stable population trends at these sites compared to previous counts in 1997 and 1998. One site (SO42) was documented as being used as a nursery colony three times in 10 years, the longest data set available for this species in Virginia. No new nursery colonies were discovered during this study, but other colonies from previous surveys were destroyed or

Table 1. The Status of Rafinesque's Big-eared Bat Structures or Sites in Southeastern Virginia

County or City	Total Structures or Sites Reported 1993-2008	Structure/Site in Good Status, 2008	Structure/Site in Good Status and Bats Present, 2006-2008	Structure/Site in Vulnerable Status, 2008	Structure/Site in Unknown Status, 2008	Structure/Site Destroyed 2002-2008	Structure/Site Destroyed Before 2002	Active Nursery Colonies 2006-2008
Chesapeake	3	0	0	0	1	0	2	0
Greensville	7	0	0	2	2	1	2	0
Hanover	1	0	0	0	1	0	0	0
Isle of Wight	2	1	1	0	0	1	0	0
New Kent	1	0	0	0	0	1	0	0
Powhatan	1	0	0	0	1	0	0	0
Southampton	51	14	7	3	13	8	13	2
Suffolk	15	4	3	2	1	1	7	0
Sussex	11	2	2	0	2	2	5	1
Virginia Beach	2	2	2	0	0	0	0	1
Total	94	23	15	7	21	14	29	4

Table 2. Annual Estimates of Rafinesque's Big-eared Bat Nursery Colonies in Southeastern Virginia.

County or City	VDGIF Site Profile	Range observed 2008	Range observed previous years	First year documented	Structure Type	Surrounding Habitat	Ownership
Southampton	SO48	30-40	30-70	2005	2-story wooden country store	hardwood forest and lake	VDGIF
Southampton	SO42	40-50	35-60	1997	2-story wooden farm house	active agricultural fields	Private
Sussex	SU10	30-45	30-40	2002	1-room wooden school house	active agricultural fields	Private with conservation easement
Virginia Beach	VB221	30	20-50	2000	concrete bunker	cypress-black gum swamp	US Navy

of unknown status. Also, in 2009 two additional nursery colonies were observed, one previously surveyed and the other newly discovered, though specific data are not included here. The nursery colonies were consistently dark rooms with minimal human activity inside the buildings; three of the structures had metal roofs.

Due to the recent trend in destruction of known roost structures, an emphasis was placed on surveying new areas. Consequently, Charles City, Prince George, and Surry counties were targeted for road cruising because these areas are considered likely to be within the range of *C. rafinesquii*, but they lack historical records (VAFWIS 2008). Road cruising in these counties and the City of Suffolk yielded approximately 80 structures with potential as bat roosts and landowner contacts were undertaken. No *C. rafinesquii* were found in structures searched in Charles City, Prince George, or Surry counties, or the City of Petersburg. Throughout southeastern Virginia, we documented 15 null sites, structures that looked suitable but had no bats present.

During this study, one newly discovered solitary roost was secured with a padlock and nursery colony sites were evaluated for structural integrity. One of the nursery colonies (VB221) is not protected from trespassers and spray paint inside the concrete bunker indicated occasional human activity there (Terwilliger Consulting, Inc. 2001). In an effort to develop and maintain landowner and public support for species protection, approximately 100 information letters were sent to landowners. We met with and discussed the status of structures and *C. rafinesquii* protection with two landowners. Furthermore, three newspaper articles were published (Virginian-Pilot, Progress-Index, and Hopewell News), an educational pamphlet (Carpenter, 2007) was written, and a children's coloring sheet (Defenders of Wildlife, 2008) was distributed to disseminate public information. Continued publicity and education are needed to enlist landowner cooperation and to locate other bat roosts.

Surveys conducted during this study yielded three new solitary bat roosts and updated VDGIF site management profiles for many previously documented nursery and solitary bat roosts. We believe fewer individuals were observed during this survey (165, versus 471 in 1997/1998) because of less intensive relative survey effort rather than a population decline. Survey information showed stable populations at the four nursery sites over consecutive years and three sites are protected and actively managed by the landowners (Table 2). Two other maternity colonies not included in this survey are protected within Great Dismal Swamp National Wildlife Refuge (D. J. Schwab, pers. comm. 2009). Surveys indicated high nursery site fidelity over many years, as large fragrant guano accumulations were observed. We believe that *C. rafinesquii* is viable in southeastern Virginia although the overall population status in Virginia is unknown. We believe that this Tier I state endangered bat species is not in current danger of extirpation, as was suggested in the Recovery Plan (Schwab et al., 1990).

It is unclear what proportion of the population uses natural roost sites versus man-made structures because of the lack of surveys and difficulty accessing roosts in tree hollows in swamps; a previous survey of 40 trees yielded only a single specimen (Hobson 1998). Threats to *C. rafinesquii* include conversion of farmland to residential development, razing of old barns and abandoned houses, and disease. Survey information will assist in revising the Recovery Plan for *C. rafinesquii* and was also sent to the U.S. Fish and Wildlife Service in response to their 2009 efforts to conduct a status review of this species. Future studies could focus on areas where no surveys have been conducted, such as Chesterfield, Henrico, and Powhatan counties. Surveys of historically occupied structures are incomplete, because there are currently 21 such structures with an unknown status. There is a great need for revisiting previously documented sites and searching for potential new structures.

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Freshwater Mussel Declines in the Upper South Fork Holston River, Virginia

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ABSTRACT

The Holston River originates in southwestern Virginia from three tributaries: South, Middle, and North forks. A freshwater mussel survey conducted between 1968 and 1974 at 16 sites in the South Fork Holston River, Virginia documented only nine species. To determine changes in the mussel assemblage, we resurveyed these sites and found a significant decrease in the number of species per site and number of sites containing mussels. Little recruitment was present in the mainly senescent mussel community. Many industrial and land-use practices in the early 20th Century could have initially contributed to these declines. As many impacts ended, the Tennessee Valley Authority completed construction of the South Fork Holston Reservoir near the Virginia/Tennessee border, which has since restricted mussel recovery in the watershed.

Key words: Virginia, Holston River, mussels, declines, impoundments.

INTRODUCTION

The South Fork of the Holston River is one of three headwater tributaries originating in southwestern Virginia. The South Fork Holston River (SFHR) is joined by the Middle Fork Holston River directly above the South Fork Holston Reservoir in Washington County, Virginia (Fig. 1). During a survey of the pre-impounded SFHR in 1901, C. C. Adams (1915) failed to locate his target organism, the spiny riversnail (*Io fluvialis* Say, 1825), but did record the presence of 10 freshwater mussel species at two Virginia sites (Ortmann, 1918). Ortmann (1918) surveyed one site in 1913 and found eight species, three of which were additions to the known mollusk fauna. Collectively, these surveys documented 13 species, including the pheasantshell, *Actinonaias pectorosa* (Conrad 1834), elktoe, *Alasmidonta marginata* Say 1818, slippershell, *A. viridis* (Rafinesque 1820), spike, *Elliptio dilatata* (Rafinesque 1820), tan riffleshell, *Epioblasma florentina walkeri* (Wilson and Clark 1914), Tennessee pigtoe, *Fusconaia barnesiana* (Lea 1838), wavyrayed lampmussel, *Lampsilis fasciola* Rafinesque 1820, flutedshell, *Lasmigona costata* (Rafinesque 1820), Cumberland moccasinshell, *Medionidus conradicus* (Lea 1834), Tennessee clubshell, *Pleurobema oviforme* (Conrad 1834), fluted kidneyshell, *Ptychobranchus subtentum* (Say 1825), rainbow mussel, *Villosa iris* (Lea 1838), and mountain creekshell, *V. vanuxemensis* (Lea 1838).

Over a 6-year period (1968-1974), Stansbery & Clench (1977) conducted the first comprehensive freshwater mussel survey above the impounded section of the SFHR, Virginia. They sampled 16 mainstem sites

and identified nine species, but did not record *A. marginata*, *A. viridis*, *E. dilatata*, *P. subtentum*, or *E. f. walkeri*, all of which were known from earlier surveys. However, Stansbery & Clench (1977) found a single specimen of littlewing pearlymussel, *Pegias fabula* (Lea 1838), which was not previously recorded from SFHR. They speculated that because the SFHR has minimal contact with calcium-bearing substrates, calcium may be a limiting factor for mollusks that have a high calcium requirement.

Similar to Virginia, the Tennessee section of the SFHR has shown dramatic declines in its once diverse unionid fauna. Collections from two prehistoric aboriginal sites and four localities surveyed by Ortmann (1918) in the lower to middle sections yielded 35 species (Parmalee & Polhemus, 2004), including all species known from Virginia SFHR except slippershell (*A. viridis*) and Tennessee clubshell (*P. oviforme*). All native riverine mussels have disappeared from the SFHR in Tennessee. In impounded reaches, the giant floater (*Pyganodon grandis*) and paper pondshell (*Utterbackia imbecillis*) have become established (Parmalee & Polhemus, 2004).

The purpose of our study was to determine changes and trends of freshwater mussel populations in the SFHR in Virginia by resurveying sites sampled by Stansbery & Clench (1977). In addition, we review historic threats in the drainage as potential causal factors for mussel declines.

MATERIALS AND METHODS

Study area

The SFHR originates near Sugar Grove, Smyth County, Virginia and flows southwestward 215 river km (RKm) before emptying into the South Fork Holston Reservoir in Washington County, Virginia (Fig. 1). Completed in 1950, the 18,730 ha reservoir extends 38.6 km to the confluence of the South Fork and Middle Fork Holston rivers in Washington County, Virginia. Land-use in the watershed is 76% forested, 21% agricultural, and 3% residential (USGS, 2003). Geology consists primarily of sedimentary and metamorphic rocks (VDMR, 2003). The SFHR headwaters and Laurel Creek are classified as trout waters by the Virginia Department of Game and Inland Fisheries (VDGIF).

Mussel sampling

Our survey was conducted from July 2000 to September 2003 and included all 16 mainstem sites (Table 1) sampled by Stansbery & Clench (1977). We spent a total of 146 survey hours with field crews ranging from 2 to 6 individuals, averaging 9 person-hours per site. Sampling was conducted during summer months to take advantage of low flow and clear water conditions. Sampling distance was calculated as 20 times average bankfull width, which allows for a series of pool, riffle, and run habitat units to be included in the sample section (Leopold et al., 1964). We selected 150 m and 500 m as the minimum and maximum distance of the sampling boundaries. A Garmin etrex unit was used to obtain geographic (Universal Transverse Mercator) coordinates.

All habitats were sampled by snorkeling by moving upstream, scanning substrate, and hand-picking mussels from the stream bottom. When possible, boulders, logs, and other large items were overturned during the search. Live mussels and shells were held underwater in mesh bags. All live mussels were identified and shell length measured to the nearest mm using dial calipers. They were then checked for gravidity, sexed, photographed, and returned to their original position. Common and scientific nomenclature follows Turgeon et al. (1998) and conservation status follows Williams et al. (1993). We used a nonparametric Wilcoxon Signed Rank test ($\alpha = 0.05$) to detect changes in species richness and abundance at each site and the number of sites inhabited by each species between the 1968-1974 and 2000-2003 surveys (Pilarczyk et al., 2006). Because $N < 20$, we used the Wilcoxon Signed Rank statistic of W+ to test for differences.

RESULTS

We collected a total of 66 live mussels of seven species at nine (56%) mainstem sites (Table 2). The most widely distributed species, *Villosa vanuxemensis*, was found at eight sites, whereas the most numerous species, *V. iris*, comprised 44% of total abundance and was the second most widely distributed species (present at 6 sites). Three species, *A. pectorosa*, *L. costata*, and *M. conradicus*, were each represented only by a single live specimen. *Fusconaia barnesiana* was represented by the collection of relic shells at two sites. We observed the greatest mussel abundance at site 12, where 21 individuals were collected, and the highest species richness (n = 5) at site 7.

In comparing our findings to those of Stansbery & Clench (1977), we found a significant decrease (W+ = -25, p = 0.0098) in the number of species per site between the two surveys. Nine sites had fewer species (mean = -2.3 species/site) during our survey, two sites contained more species (mean = +1.5 species/site) than during the previous survey, and five sites had an equal number of species during both surveys.

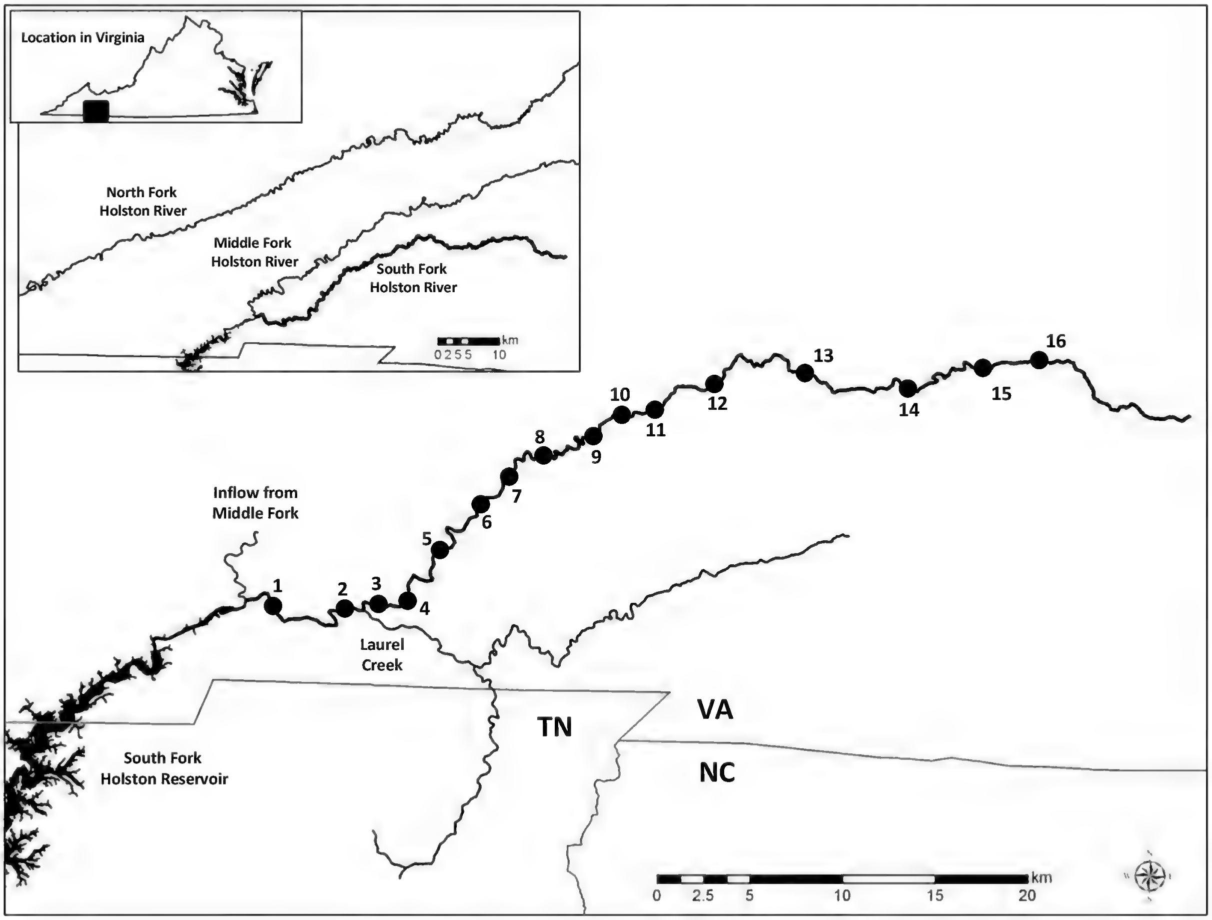

Fig. 1. Mussel survey sites on the South Fork Holston River, Washington and Smyth counties, Virginia.

Table 1. South Fork Holston River site locations surveyed between 2000 and 2003.

Site	RKm	UTM X	UTM Y	Location
1	118.4	420794	4056642	Alvarado (Barrow)
2	124.2	424498	4056335	Drowning Ford (Hwy 58)
3	127.5	427338	4056650	Rambeaux Bridge
4	128.9	428195	4057255	Wright Bridge (Hwy 91)
5	133.7	430070	4059620	Mast Bridge
6	138.2	432113	4062233	Buck Bridge
7	140.2	433286	4063734	1.6 km SSW Friendship
8	143.2	435152	4064715	Little Rock Church Ford
9	149.7	438333	4066174	4.8 km ENE Friendship
10	150.8	439114	4067052	Love's Mill
11	152.7	440655	4067120	2.2 km SW St. Clair Bottom
12	158.2	445078	4069246	4.3 km W Thomas Bridge
13	166.5	450874	4068480	1.1 km above Thomas Bridge
14	171.4	455186	4068515	Quebec
15	178.6	459708	4069793	Teas
16	180.4	461442	4069919	Roberts Mill

Site 4 demonstrated the sharpest decrease, with a loss of six species.

We observed a significant decrease (W+ = -18, p = 0.0078) in the number of sites containing live mussels compared to the 1968-1974 surveys (Fig. 2). All species with the exception of *L. fasciola* demonstrated a decline in the number of sites of occurrence between the two studies, with *L. costata* demonstrating the largest decrease (five sites in 1968-1974 versus one in 2000-2003). Neither *P. fabula* nor *F. barnesiana* were collected during our survey.

Stansbery & Clench (1977) did not report species abundance by site but noted abundance by species over the entire survey. While abundance was not significantly different (W+ = -.500, p = 0.984) between the two surveys, we observed greater abundance of *V. vanuxemensis*, *V. iris*, *P. oviforme*, and *L. fasciola*, and declines in abundance in *A. pectorosa*, *L. costata*, *M. conradicus*, *P. fabula*, and *F. barnesiana*.

Table 2. The number of live freshwater mussels collected during sampling of mainstem sites of the South Fork Holston River, Virginia between 2000 and 2003 (R = Relict, x = species collected by Stansbery and Clench between 1968 and 1974).

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Rkm	118.4	124.2	127.5	128.9	144.7	138.2	140.2	143.2	149.7	150.8	152.7	158.2	166.5	171.4	178.6	180.4		
Mussel species																	**# of sites**	**Total live**
Actinonaias pectorosa	Rx		1x	Rx	R	R	Rx										1	1
Fusconaia barnesiana			Rx	x		R											0	0
Lampsilis fasciola	2		1x	Rx	2x	x	1										4	6
Lasmigona costata	x		x	x	x	1	x										1	1
Medionidus conradicus				x		x	1x										1	1
Pegias fabula				x													0	0
Pleurobema oviforme	R		Rx	1x	4x	Rx	4x	1									4	10
Villosa iris	x		3x	2x	Rx	3x	3x	1x	R	1	x	16x					7	29
V. vanuxemensis	x	x	3x	4x	1x	1x	2x	1x		1	x	5x		x			8	18
Total live mussel species (2000-03)	1	0	4	3	3	3	5	3	0	2	0	2	0	0	0	0	9	-
Total live mussels	2	0	8	7	7	5	11	3	0	2	0	21	0	0	0	0	-	66
Total species (1968-74)	4	1	7	9	5	5	6	2	0	0	2	2	0	1	0	0		
Change in number of mussel species (1968-74 vs. 2000-03)	-3	-1	-3	-6	-2	-2	-1	+1	0	+2	-2	0	0	-1	0	0		

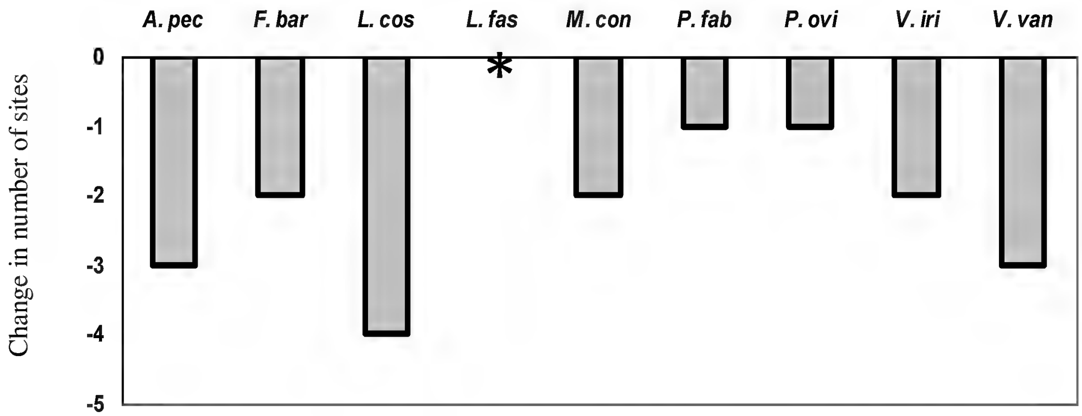

Fig. 2. Change in number of sites containing mussel species reported from 1968 to 2003 in the South Fork Holston River, Virginia. *A. pec* = *Actinonaias pectorosa, F. bar* = *Fusconaia barnesiana, L. cos* = *Lasmigona costata, L. fas* = *Lampsilis fasciola, M. con* = *Medionidus conradicus, P. fab* = *Pegias fabula, P. ovi* = *Pleurobema oviforme, V. iri* = *Villosa iris, V. van* = *Villosa vanuxemensis,* * = no change

With the exception of *V. iris* and *V. vanuxemensis*, the majority of specimens that we collected were old individuals with highly-eroded valves. Mean shell lengths for the three most abundant species were 81.49 mm (±1.89 SE) *P. oviforme*, 55.31 mm (±1.90 SE) *V. iris*, and 52.52 mm (±1.59 SE) *V. vanuxemensis*. Gravid individuals of *L. fasciola*, *P. oviforme*, and *V. iris* were found during the survey, but only *V. iris* showed evidence of recruitment (two specimens ≤ 30 mm shell length).

DISCUSSION

Our findings are similar to other studies that demonstrate a continual decline in species presence in the SFHR (Ortmann, 1918; Stansbery & Clench, 1977; Parmalee & Polhemus, 2004). Since the beginning of the 20th Century, the freshwater mussel assemblage has declined from 14 to 7 species with only one (*V. iris*) demonstrating recruitment.

Two federally endangered mussels, *E. f. walkeri* and *P. fabula*, were collected during previous surveys of the SFHR. Both are sparsely-distributed in a few cool, headwater tributaries of the Tennessee and Cumberland River systems (Parmalee & Bogan, 1998). Recent collections of *P. fabula* in Virginia include three individuals in the upper North Fork Holston River (Ahlstedt & Saylor, 1995-1996) and one in the upper Clinch River (Jones et al., 2001). In Virginia, one *E. f. walkeri* specimen was found in the Middle Fork Holston River in 1997 (Henley et al., 1999), while a reproducing population remains in the upper Clinch River watershed in Indian Creek, Tazewell County (Winston & Neves, 1997). The absence of both species during our surveys indicates that they may be extirpated from the SFHR system.

Our sampling techniques had several advantages over those of Stansbery & Clench (1977). Their sampling method was a visual search by wading (D. Stansbery, pers. comm.). We sampled by snorkeling, which is typically more effective than wading, and is more amenable to detecting small, cryptic species (Strayer & Smith, 2003). Also, the previous survey sampled a small area with less search effort (D. Stansbery, pers. comm.). Our average sampling distance was over 424 m, which allowed us to sample multiple pool/riffle/run habitat sequences. Although our sampling methods were rigorous, we were unable to match species richness or abundances compared to those of earlier efforts, thus an indication that mussel population declines are likely more severe than previously reported.

The precipitous decline of freshwater mussels in the drainage is perplexing. Stansbery & Clench (1977) claimed that stream temperature and available calcium, among other factors, may limit certain mussel species in the SFHR. Indeed, we did not find mussels in the most upstream sites typical of these conditions. In lower mainstem sections where water quality, temperature, and physical habitat were suitable, mussels were still absent or diminished indicating that the current condition of the mussel fauna could be a legacy of past disturbances from reservoirs, industrial pollution, and land-use practices in the watershed.

The impoundment of free-flowing reaches has eliminated 35 mussel species from the middle to lower SFHR, Tennessee (Parmalee & Polhemus, 2004). Within the impounded reach, freshwater mussels and obligate riverine fish species essential for their reproductive life-cycle are negatively affected by

increased sedimentation and depth, altered flows and thermal regimes, and anoxia (Neves et al., 1997). Below impoundments, mussels are affected by coldwater releases during summer months, low dissolved oxygen, disruption of seasonal flows, sediment scour, and changes in fish-host availability (Vaughn & Taylor, 1999). To overcome these stressors, a considerable distance is required below the reservoir to restore the mussel assemblage to pre-impoundment abundance and richness (Vaughn & Taylor, 1999). Because dams and impoundments occur throughout the SFHR in Tennessee, it is unlikely that any mussel assemblage can be restored to pre-impoundment levels.

Fragmentation of rivers by reservoirs can isolate aquatic species and lead to reduction in genetic flow and variation (Pringle, 1997). Because mussels are long-lived invertebrates with low rates of recruitment, the lag between the perturbation and population decline can take decades (Neves et al., 1997). Since Stansbery & Clench (1977) observed significant species losses only 18 years after the South Fork Holston dam was created, it is unlikely that the reservoir, although a factor, could alone account for the dramatic decline in mussel diversity.

Other potential causes that may have contributed to mussel declines in the SFHR include past industrial land-use practices. The upper SFHR watershed was historically mined for manganese, lead, barite, zinc, and iron (Miller, 1944). Of these, manganese mining is the most destructive because it requires the washing of clay and soil from hard ore. Ore washers were located at several sites along streams and creeks in the upper watershed, resulting in heavy sedimentation. Manganese mines left large barren pits that were a constant source of sediment. Most manganese mining occurred prior to 1919 and after 1937 due to World War I and II, which halted the import of foreign ore. No mineral mining currently occurs in the upper watershed and many sites have been restored as part of efforts by the U.S. Forest Service (USFS), Tennessee Valley Authority, and the Virginia Department of Game and Inland Fisheries (C. Thomas, USFS retired, pers. comm.).

In addition to mining, several other industries may have contributed to declines of the SFHR mussel populations. Extensive logging occurred throughout the SFHR watershed from 1900-1930 (Wilson, 1932). No best management practices to reduce sediment runoff were employed during this time. A wood tannin extract facility, reported to be the second largest of its kind in the world, operated at Teas (RKm 178.7) between 1910 and 1925 (Wilson, 1932). During this period, the facility processed 200 cords of wood per day to produce an estimated 1,137 liters (300 gallons) of concentrated liquid wood tannin extract. A textile dye plant was present at Damascus on Beaverdam Creek (a tributary of Laurel Creek), from 1918-1985. The operation specialized in sulfur dyes which use aromatic hydrocarbon intermediates such as benzene, naphthalene, diphenylamine, and azobenzene as starting materials (Colorants Industry History, 2005). Although no water quality records exist for these industries, they undoubtedly had a negative and lasting impact on the SFHR biota many miles downstream.

Even with the documented declines of the mussel fauna in the SFHR, there are some positive signs for its recovery. Since 1998, the VDGIF has operated a mussel cultivation facility (Aquatic Wildlife Conservation Center) at RKm 168.2. The facility holds over 32 mussel species primarily from the upper Clinch River. Using SFHR water, the operation has demonstrated high mussel growth and survival. Between 2005 and 2010, VDGIF has translocated 275 adults of five species from the Middle Fork Holston River to the SFHR at Rkm 140.2. At the same SFHR location, 12,316 one-week to five-month old propagated *V. vanuxemensis* were released. Unfortunately, no concerted effort has been attempted to monitor these releases. Future monitoring will be necessary to determine if translocation and propagation are successful strategies in restoring the freshwater mussels of the SFHR.

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Historical Records of *Nicrophorus americanus* (American Burying Beetle) from Virginia and Vicinity, and Confirmation of the Occurrence of *N. carolinus* in Virginia (Coleoptera: Silphidae)

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ABSTRACT

Nicrophorus americanus is a federally endangered beetle that was last collected in Virginia in 1955. All known historical records of this species from Virginia, North Carolina, Maryland, and the District of Columbia are reviewed. The alleged existence of *Nicrophorus carolinus* in Virginia is substantiated for the first time. Historical records of this species from North Carolina, West Virginia, and Maryland are reviewed.

Key words: beetle, distribution, endangered species, Coleoptera, *Nicrophorus*, Silphidae, Maryland, North Carolina, Virginia, West Virginia, District of Columbia.

INTRODUCTION

Although at least three volumes (Linzey, 1979; Terwilliger, 1991; Terwilliger et al., 1995) have treated the rare, threatened, and endangered flora and fauna (including selected insects) of Virginia in great detail in recent decades, none of them includes mention of *Nicrophorus americanus* Olivier, the American burying beetle. Davis (1980) and Anderson (1982) first noted apparent scarcity or population declines of this large, wide-ranging carrion beetle, and Kozol et al. (1988) conducted the first detailed ecological study of this species. Like all *Nicrophorus*, this species, the largest North American member of the genus, exhibits extended biparental care of its young, and both adults and larvae feed on carrion. In 1989, *N. americanus* was listed as a federally endangered species due to widespread population declines during the previous century (U.S. Fish and Wildlife Service, 1991). Once found throughout eastern United States (it was historically documented from at least 150 counties in 35 states) as well as extreme southeastern Canada, the range of *N. americanus* has been reduced by more than 90% from its historical extent (Anderson & Peck, 1985; Peck & Kaulbaurs, 1987; U.S. Fish and Wildlife Service, 1991). At the time of its official listing as endangered, this species was thought to persist only on one island off the coast of Rhode Island (i.e., Block Island) and in four counties in eastern Oklahoma (U.S. Fish and Wildlife Service, 1991). Its new legal status brought increased attention to this species in the form of inventory and research studies (e.g., Ratcliffe & Jameson, 1992; Creighton et al., 1993; Lomolino & Creighton, 1996; Amaral et al., 1997; Backlund & Marrone, 1997; Guarisco, 1997; Holloway & Schnell, 1997; Lomolino et al., 1997; Miller & McDonald, 1997; Carlton & Rothwein, 1998; Creighton & Schnell, 1998; Bedick, et al. 1999; Walker & Hoback, 2007; Backlund et al., 2008). Some of these inventory efforts resulted in the documentation of additional extant

populations of *N. americanus* at the western periphery of its historical range, including sites in six states (Arkansas, Oklahoma, Texas, Kansas, Nebraska, and South Dakota), but the species has not been rediscovered anywhere in the East.

The Block Island population remains the only known, naturally-occurring extant population east of the Mississippi River. Raithel et al. (2006) summarized the results of a long-term monitoring study on this population, and reported that supplemental provisioning of carrion resulted in an increase in the population size, perhaps suggesting that availability of carcasses is a limiting factor. Captive rearing and reintroduction methods (in southeastern Ohio and two islands off the coast of Massachusetts) have also been employed in an effort to re-establish additional populations in the East (Amaral et al., 1997; Dikeman, 2009; Selbo, 2009).

More recently, Szalanski et al. (2000) analyzed the population genetic structure of *N. americanus* and Bedick et al. (2004) evaluated a number of sampling methods for *N. americanus* that involved the use of baited pitfall traps of various sizes and designs, and suggested changes to the official standard protocol approved by the U.S. Fish and Wildlife Service. Sikes & Raithel (2002) reviewed eight hypotheses that might account for the rather sudden decline of this species. These hypotheses include the possibility that an unknown pathogen could have caused widespread declines of *N. americanus* or that reduced availability of large vertebrate carrion within the past century, perhaps as a result of factors such as habitat degradation or fragmentation, increased competition from vertebrate scavengers, or even the extinction of the once extremely abundant Passenger Pigeon (*Ectopistes migratorius*), might account for the observed decline. Since *N. americanus* seems to be a habitat generalist (e.g., Lomolino et al., 1995; Backlund & Marrone, 1997; Creighton & Schnell, 1998), the loss of any particular type of habitat does not appear to be a satisfactory explanation. Sikes & Raithel (2002) concluded that more research is needed to evaluate the various hypotheses before a better understanding of the precipitous decline of *N. americanus* can be obtained.

REGIONAL DISTRIBUTION OF *NICROPHORUS AMERICANUS*

In the virtual absence of inventory surveys for most groups of insects in Virginia, the disappearance of *N. americanus* from the Commonwealth essentially went unnoticed. We are aware of a total of 15 historical adult specimens that were collected in the state and take this opportunity to document these records. Twelve of the specimens are deposited in the National Museum of Natural History (NMNH), Smithsonian Institution, Washington, D.C., and one each resides in the insect collections of Harvard University (MCZ, Cambridge, Massachusetts), Virginia Polytechnic Institute and State University (= Virginia Tech; VPISU, Blacksburg, Virginia), and the Virginia Museum of Natural History (VMNH, Martinsville, Virginia). These specimens came from the following five or six localities:

1. Nelson County, June 1896 (MCZ, 1; specimen not examined). Perkins (1983) and U.S. Fish and Wildlife Service (1991) do not provide a specific locality (or collector), but we suspect the specimen was obtained by Col. Wirt Robinson, a naturalist/collector who resided at Wingina along the James River during that period.

2. Fredericksburg [Spotsylvania Co.] - three old specimens, including two collected on 25 May 1900 and the other one lacking a date (probably ca. 1900); collector's name lacking from all labels (NMNH, 3♂) but we suspect it may have been W. D. Richardson, a local naturalist/collector during that period.

3. Richmond (city) - six specimens, including a male and female collected on 24 July 1927 and 5 August 1927, respectively, and four others lacking dates (probably ca. 1920-30); all specimens collected by George W. Barber (NMNH, 3♂, 3♀). According to the pin labels, the four specimens lacking dates were taken on turtle carcasses during a scavenger study and were part of the S. W. Bromley insect collection that was donated to NMNH in 1955.

4. Essex County, [unspecified locality], 22 May 1932, C. L. Pace, "On dead snake" (VMNH, 1♀, ex UR collection).

5. Montgomery County, [unspecified locality and collector but likely Ellison A. Smyth, Jr.], 26 June 1900, 20 May 1910, and 20 May 1911 (NMNH, 3♀). Smyth was head of the biology department at Virginia Tech during this time period (Mitchell & Kosztarab, 1998) and collected insects locally in Blacksburg as well as nearby Poverty Hollow (ca. 8 km north of Blacksburg). SMR has seen many of Smyth's Lepidoptera specimens at NMNH (mostly) and VPISU, most of which do not bear his name as the collector and often only list the county name (Montgomery) rather than also include Blacksburg on the label (very few

labels specify Poverty Hollow as the collection site).

6. Montgomery Co., Blacksburg, August 1955, [no collector specified] (VPISU, 1♀). This is the last known specimen of *N. americanus* documented in Virginia.

The United States range maps for *N. americanus* prepared by Perkins (1983) and Peck & Kaulbars (1987) (as well as those published in U.S. Fish and Wildlife Service, 1991, Lomolino et al., 1995, Holloway & Schnell, 1997, and Sikes & Raithel, 2002) show four localities in Virginia, which correspond to records 1-3 and 5 above. During the past two decades, staff of our respective agencies (as well as several other researchers, most notably Joseph C. Mitchell and Arthur V. Evans) have conducted extensive pitfall and/or blacklight trapping throughout Virginia and captured thousands of *Nicrophorus* specimens, but *N. americanus* was not among these, suggesting that this species is likely extirpated from the state.

Other historical localities nearest to Virginia include the District of Columbia, one site on the Eastern Shore of Maryland (Dorchester Co., Cambridge, [collector unknown], 25 June 1947, Florida State Collection of Arthropods (FSCA), 1; same but August 1939, Natural History Society of Maryland, 1; specimen not examined) and two sites each in western North Carolina and eastern Tennessee (the most recent collections from these states were made in 1940 and 1955, respectively, fide U.S. Fish and Wildlife Service [1991]; see also Walker [1957] and Anderson [1982]). Historical specimens of *N. americanus* from the District of Columbia include those housed in the American Museum of Natural History (1895, n = 1; AMNH), Carnegie Museum of Natural History (no dates, n = 2; CMNH), MCZ (1931, n = 1), and NMNH (1890-1902, n = 5) (SMR, pers. obs. and data in Perkins [1983]). At least seven other Maryland specimens exist (MCZ, 3; University of Maryland, 4 [four other specimens in this collection lack locality data but they apparently were presumed to be of Maryland origin by Staines (1987), who reported 8 specimens]), but they only contain state labels and lack collection data (Perkins, 1983; Staines, 1987; Roble, pers. obs.). No records of *N. americanus* were plotted for West Virginia by Perkins (1983) or Peck & Kaulbars (1987), and we are not aware of any subsequent reports from that state. This species was last documented in Kentucky (Land Between the Lakes region in southwestern corner) much later than in each of the states discussed above (Trigg Co., Hematite Lake, T. Jeffards, 18 July 1974, FSCA, 1).

Brimley (1938) recorded *N. americanus* from five localities in North Carolina: Beaver Creek (Ashe Co.), Morganton (Burke Co.), New Bern (Craven Co.), Raleigh (Wake Co.), and Southern Pines (Moore Co.). None of these records was included in the summaries prepared by Perkins (1983) or Peck & Kaulbars (1987). Apparently, the most recent specimen (in Field Museum of Natural History) of *N. americanus* from North Carolina was taken at Black Mountain (Buncombe Co.) in 1940 (Perkins, 1983; U.S. Fish and Wildlife Service, 1991). Perkins (1983) and Peck & Kaulbars (1987) did not examine the North Carolina State University collection, which contains five specimens of *N. americanus* from North Carolina, including two obtained at localities not mentioned by Brimley (1938): Erwin (Harnett Co.), 1938; Asheville (Buncombe Co.), 1935; New Bern, 1935; Beaver Creek, 1915; and Raleigh, 1901. Five additional specimens (AMNH) of this species were collected in 1904 in the Black Mountains of western North Carolina (Perkins, 1983). It is likely that these specimens were collected on or near Mount Mitchell (Yancey Co.) by E. C. Van Dyke or William Beutenmuller, both of whom were active beetle collectors in this region at that time. Collectively, the above sources account for a minimum of nine known historical sites for *N. americanus* in North Carolina (Fig. 1).

REGIONAL DISTRIBUTION OF *NICROPHORUS CAROLINUS*

A related species of potential conservation concern in Virginia is *Nicrophorus carolinus* (Linnaeus). Anderson & Peck (1985) stated that the range of this species extends "from the central states south to Texas and Arizona, east along the Gulf Coastal Plain to Florida, then north along the Atlantic Coastal Plain to Virginia." They also cited a specimen record from southeastern Alberta, the only documentation of this species from Canada. Peck & Miller's (1993) catalog listed Virginia, Maryland, and New York as the northernmost extent of the range of this species in the East. However, Peck & Kaulbaurs (1987) did not plot locality records in any of these states (or West Virginia) on their map for *N. carolinus*, their northernmost records east of the Mississippi River being four localities in southeastern North Carolina. When queried for data on Virginia specimens of *N. carolinus*, Peck responded (*in litt*., 1994) that he had no actual records of this species from Virginia (or Maryland and New York), but he did confirm the existence of an unpublished record for West Virginia (Hardy Co.,

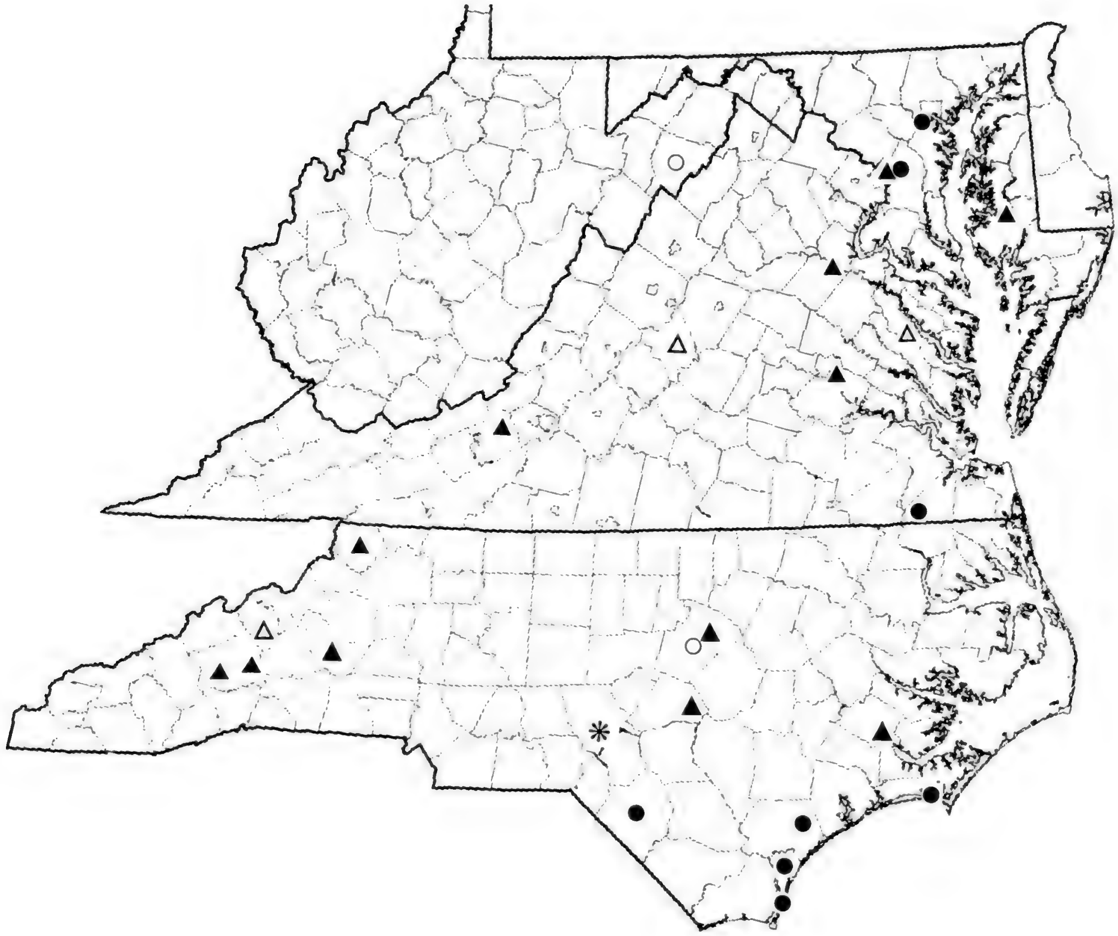

Fig. 1. Known distribution of *Nicrophorus americanus* (triangles; all records 1955 or older) and *Nicrophorus carolinus* (circles; all records 1968 or older except for Suffolk, Virginia) in Virginia and adjacent states. Closed symbols indicate specific localities and open symbols denote county or other general records. The asterisk marks the only documented sympatric locality (Southern Pines, North Carolina); Aberdeen is proximate to Southern Pines and not indicated by a separate symbol. College Park and Greenbelt, Maryland are represented by the same dot. "Dundee" North Carolina appears to no longer exist; the symbol for that locality is therefore centered on Robeson County.

3 August 1966, R. Martin, West Virginia Department of Agriculture collection, 1). Staines (1987) reported *N. carolinus* from Frederick (Ijamsville, 18 May 1898) and Prince Georges (College Park, 20 June 1941; Greenbelt, 8 May 1961) counties in Maryland, but we believe the first record is in error and represents a misreading of the handwritten collection label that actually contains the following data: Lansdowne [Baltimore Co.], Maryland, 28 May 1898 (University of Maryland, 1). In addition to the 1941 specimen from College Park, the University of Maryland collection contains a second specimen from the same locality ("College, Md.") taken in September 1893.

The following specimens conclusively document the occurrence of *N. carolinus* in southeastern Virginia: "S. of Franklin, Va. / 8 IX 1937 / Carroll Williams, Coll." (VMNH, 1♀, ex UR collection); City of Suffolk, South Quay pine barrens, ca. 6 mi SSE Franklin, xeric pine woods 100 m N of canal, 2 July-6 August 2003, pitfall trap, S. M. Roble (VMNH, 1♂). **NEW STATE RECORD**.

The South Quay site is within 0.5 km of the North Carolina border and is one of the most xeric, sandy habitats known in Virginia. We suspect that the 1937 specimen, the existence of which went undetected until May 2010 when RLH discovered it amongst a series of unidentified beetles in the former University of Richmond (UR) collection, was collected in the same

general area. Carroll Williams, the collector of this specimen, was an entomologist and junior faculty member in the biology department at the University of Richmond in the mid-1930s. He often accompanied (and served as the driver for) renowned Harvard University botanist Merritt Fernald during the latter's collecting trips to southeastern Virginia, which included several excursions to the South Quay pine barrens (Fernald, 1937, 1938). Williams later joined the faculty at Harvard for the duration of his career.

Brimley (1938) recorded *N. carolinus* from four localities in North Carolina: Aberdeen (Moore Co.), Dundee (Robeson Co.), Southern Pines (Moore Co.), and Wilmington (New Hanover Co.). The NCSU collection has six specimens of this species from that state, confirming Brimley's reported localities and adding two later records: Wake County [no further details], 19 August 1968, W. M. Kulash (1); Holly Shelter [State Game Lands, Pender Co.], 6 October 1965, D. Weisman (1); Dundee, 9 November 1926, T. B. Mitchell (1); Aberdeen, 7 July 1922, E. W. Leiby (1); Southern Pines, 24 November 1909, [presumably A. H. Manee] (1); and Wilmington, 11 November (no year on label), M. Kisciuk (1). All of these records are from the Coastal Plain. The North Carolina specimens (n = 15; data sheets provided by S. Peck) of *N. carolinus* examined during the study by Peck & Kaulbars (1987) reside in one private (H. F. Howden) and four museum collections and were taken in Beaufort (Carteret Co., [no further details], MCZ, 2), Carolina Beach (New Hanover Co., 15 August 1935, S. W. Bromley, NMNH, 1), Holly Shelter (5 June 1951, H. F. Howden, 1), Southern Pines (24 June 1920, A. N. Manee, Canadian National Collection (CNC), 2; 11 July 1920, A. N. Manee, CNC, 1; November [no further details], INHS, 1), and Wilmington (1 August [no year], [G. P.] Englehardt, NMNH, 1). Six additional specimens (MCZ, 5; NMNH, 1) only have state labels and lack dates, but the latter specimen was obtained by Henry G. Hubbard and Eugene A. Schwarz who were active beetle collectors in the late 19th century. The Illinois Natural History Survey (INHS) collection actually contains eight (not one) historical specimens of *N. carolinus* from North Carolina (C. Dietrich, pers. comm.), all but one taken at Southern Pines (16 July 1911, 20 September 1911, 1 November 1911, 17 September 1913, and 23 April 1914, all A. N. Manee; two additional specimens from Southern Pines lack dates and collector names). The other INHS specimen, collected on 5 October 1917, only has a state label and no collector is indicated. We do not know if *N. carolinus* has been collected in North Carolina in the past four decades. The regional distribution of this species is shown in Figure 1.

Anderson & Peck (1985) stated that "*N. carolinus* appears restricted to sandy soil in open or sparsely forested areas" and remarked that little else was known about its natural history other than Arnett's (1946) observations of adults burying a dead snake. Peck & Kaulbars (1987) noted that this species has been found in open forests, grasslands, shrub steppe, and creosote bush desert habitats, with adult collection dates ranging from March to October. Perhaps future sampling in southeastern Virginia will reveal the presence of additional populations of *N. carolinus.*

ACKNOWLEDGEMENTS

We thank Michael Kosztarab (VPISU), Warren Steiner (NMNH), Robert Blinn (NCSU), John Rawlins (CMNH), Michael Thomas (FSCA), and Charles Mitter (University of Maryland) for granting access to collections in their care. Chris Dietrich provided data on *N. carolinus* specimens in the Illinois Natural History Survey (INHS) collection. Stewart Peck (Carleton University, Ottawa, Canada) generously provided photocopies of his museum data sheets for *N. carolinus* and Philip Perkins (MCZ) provided data from his unpublished report (1983). Margaret Ormes (NatureServe, Boston, Massachusetts) scanned the *N. americanus* pages in Perkins' report for us, and Lynn Davidson (Maryland Department of Natural Resources, Wildlife and Heritage Service, Natural Heritage Program) and Charlie Staines (NMNH) provided information on historical records of *N. americanus* and *N. carolinus* in Maryland. The comments of several anonymous reviewers are appreciated.

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The Cicada Parasite Beetles (Coleoptera: Rhipiceridae) of Virginia

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ABSTRACT

The family Rhipiceridae is represented in Virginia by two species, *Sandalus niger* Knoch and *S. petrophya* Knoch, the latter of which is documented from the state for the first time.

Key words: cicada parasite beetle, new state record, Rhipiceridae, *Sandalus*, Virginia.

INTRODUCTION

The Rhipiceridae, also known as cicada parasite or cedar beetles, is a small family with more than 100 species in seven genera (Lawrence, 2005). The family is represented in the Nearctic region by *Sandalus* (Greek σανδαλον, or sandals), a genus proposed by Knoch (1801) to include two North American species *S. petrophya* and *S. niger*. *Sandalus* occurs in the New World, Africa, southeast Asia, China, India, and Japan (Katovich, 2002) and is in need of revision. The Nearctic fauna currently consists of five species, three of which occur in eastern North America. Of these, only two, *S. niger* Knoch and *S. petrophya* Knoch, occur in Virginia. The third species, *S. porosus* LeConte, ranges from Florida west to Colorado and Arizona (Katovich, 2002).

The common name "cedar beetle" was most likely instigated by LeConte's (1862) statement that the Rhipiceridae was "A family containing a small number of species, found on plants; *Sandalus* especially affecting various cedars…" and popularized by Blatchley (1910) and Arnett (1963). The more recent moniker "cicada parasite beetles," first coined by Downie & Arnett (1996), is more descriptive given the available information on the larval biology of *Sandalus*. As noted by Dodge (1941), the "apparent association with certain trees has no significance except as it may indicate host or oviposition preferences of the host cicada."

METHODS

This study is based on our own field work, literature records, and the examination of specimens housed in the following collections: Virginia Museum of Natural History, Martinsville, Virginia (VMNH); Virginia Polytechnic Institute and State University, Blacksburg, Virginia (VPIC); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (NMNH); George Washington Memorial Parkway, Turkey Run Park, McLean, Virginia (GWMP); Arthur V. Evans, Richmond, Virginia (AVEC).

RESULTS AND DISCUSSION

Adult *Sandalus* are long (15-24 mm), convex, reddish brown or black (sometimes bicolored) and coarsely punctured beetles (Fig. 1); females are typically larger than males. The head has bulging eyes,

Fig. 1. *Sandalus petrophya* Knoch, female.

prominent hypognathous mandibles, and 11-segmented antennae that are distinctly flabellate in males and more or less serrate in females. The prothorax becomes wider posteriorly and is narrower than the base of the elytra. The long, vaguely ribbed and coarsely punctured elytra completely conceal the abdomen, which has five visible sternites. The tarsal formula is 5-5-5. Tarsomeres 1-4 are heart-shaped with membranous lobes and the claws are simple and equal in size.

Very little is known about the biology of rhipicerid beetles, with the exception of *S. niger*. Adults of this species do not feed and reach peak activity from late September through early October (Rings, 1942; Elzinga, 1977; Katovich 2002). They are found resting on tree trunks or grass, in Malaise trap samples, and are occasionally attracted to lights.

Elzinga (1977) observed mating aggregations of *S. niger* on the trunks of American Elm (*Ulmus americanus*), Shingle Oak (*Quercus imbricarius*), beech (*Fagus*), ash (*Fraxinus*), and other hardwoods. Adults emerge from their burrows in the morning and crawl up trunks to mate. Females lay large numbers of eggs in the holes and cracks of bark, preferably in areas where there are numerous cicadas. Rings (1942) noted that a single female could produce more than 16,000 eggs. Craighead (1921) proposed that the larvae of *S. niger* develop as ectoparasitoids of immature cicadas after discovering a pupa and cast larval exoskeleton of the beetle within a dead and hollowed-out cicada nymph. This assertion was later supported by descriptions of the first instar triungulin of *S. niger* (Dodge, 1941; Elzinga, 1977) that is typical of other beetle parasitoids. The larval stages between the triungulin and pupa remain unknown.

The adults of *Sandalus* in Virginia are distinguished by the characters in the key below.

Key to the Adult *Sandalus* of Virginia
(after Staines, 1982)

Sides of prothorax uniformly narrowed from posterior to anterior (Fig. 2), keel weakly developed, especially at basal third (Fig. 3) (17-25 mm).. *Sandalus niger* Knoch

Sides of prothorax subangulate behind middle (Fig. 4), and distinctly keeled throughout (Fig. 5) (12-18 mm)............................. *Sandalus petrophya* Knoch

Sandalus niger Knoch

This species is known from southern Ontario to Florida, west to Colorado and Texas. **Canada:** Ontario (Hicks, 1942). **United States:** Alabama, Colorado, District of Columbia, Florida, Georgia, Indiana, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Missouri, Nebraska, New Jersey, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, West Virginia, and Wisconsin (Brimley, 1938; Downey & Arnett, 1996; Dury, 1879, Elzinga, 1977, Craighead, 1921, Young & Katovich, 2002; Kirk, 1969, 1970; Leng, 1928; Manee, 1908; Rings, 1942; Skelley, pers. comm.; Staines, 1982; Ulke, 1902; Young, 2002). Specimens have been examined from the following counties and cities in **Virginia**: Alexandria (City), Chesapeake (City), Fairfax, Franklin, Montgomery, Richmond (City), Scott, and Shenandoah. (AVEC, GWMP, NMNH, VMNH, VPIC). In Virginia, individuals of *S. niger* have been found from July through November. This species is widespread in Virginia (Fig. 6) and has been collected in the Coastal Plain, Piedmont, Appalachian Plateau, and Valley and Ridge physiographic regions.

Sandalus petrophya Knoch
NEW STATE RECORD

This species occurs from New York to Florida, west to Indiana, Missouri, and Alabama, but has not been reported from Virginia previously. **United States:** Alabama, District of Columbia, Florida, Georgia, Illinois, Indiana, Kentucky, Louisiana, Maryland, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia (Blatchley, 1910; Carlton, pers. comm.; Downie & Arnett, 1996; Dury, 1882; Leng, 1928; Say, 1835; Peck & Thomas, 1998; Smith, 1900; Staines, 1982; Ulke, 1902).

Fig. 2. Dorsal view of prothorax of *Sandalus niger* Knoch, male (top) and female (bottom).

Fig. 3. Lateral prothoracic margin of *Sandalus niger* Knoch.

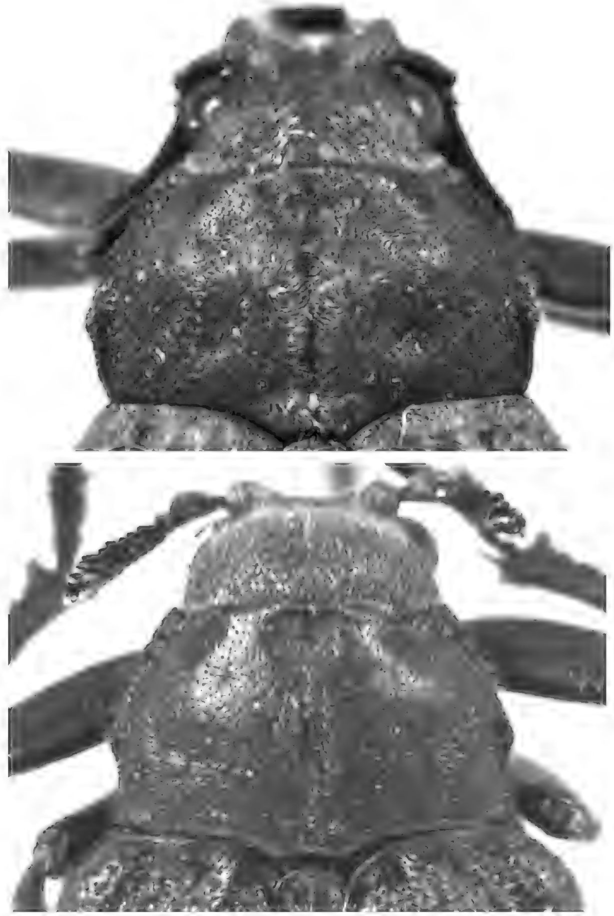

Fig. 4. Dorsal view of prothorax of *Sandalus petrophya* Knoch, male (top) and female (bottom).

Fig. 5. Lateral prothoracic margin of *Sandalus petrophya* Knoch.

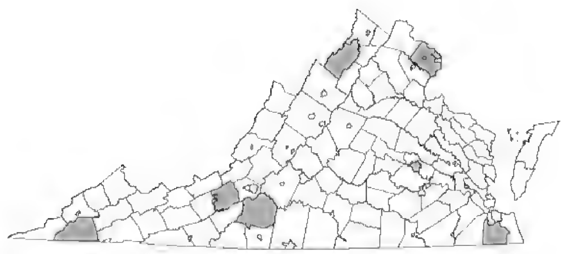

Fig. 6. County and city distribution map for *Sandalus niger* Knoch based on specimens examined from Virginia.

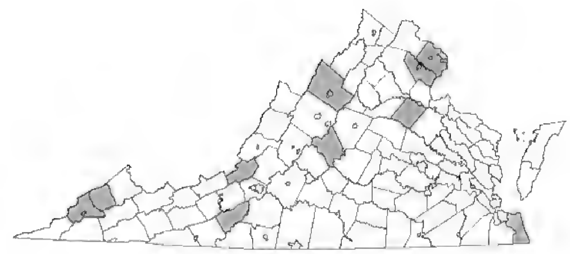

Fig. 7. County and city distribution map for *Sandalus petrophya* Knoch based on specimens examined from Virginia.

Sandalus petrophya has been found in the following counties and cities in **Virginia**: **Alexandria (City):** Del Ray, 27 October 2000, R. B. & A. Faden (1); Washington Golf Club, Jewell, 16 August 1925, L.L. Buchanan (1). **Craig Co.:** Jefferson National Forest, FR 620, 12 August 1997, M. W. Donahue (1). **Dickenson Co.:** Breaks Interstate Park, 1-14 July 2000, R. Vigneault (1). **Fairfax Co.:** parking lot, Turkey Run Park Headquarters, McLean, 20 July 2006, B. W. Steury (1); same data, except 28 July 2009 (1); 2 mi. SW Vienna, 30 July 1932, J. C. Bridwell (1); Vienna, 23 July 1913, R. A. Cushman (1); W Falls Church, VI-28-1917, on oak tree, J. L. Wrenn (1); Falls Church, 18 July 1914, H. B. Kirk; same data except 13 August 1914, G. M. Greene (1); same data except 14 August 1914 (2); same data except 7 August 1914 (1); same data except 26 August 1917 (1); Springfield, 26-29 July 1968, Joseph W. Adams (2); Black Pond, 29 June 1914, E. Shoemaker (1); Dead Run, 6 August 1915, R. C. Shannon (1); Great Falls, VII.4 [no year] (1). **Floyd Co.:** county only, 23 August 1982, M. W. Allen (2). **Nelson Co.:** county only, 1 August 1917, W. Robinson (14). **Prince William Co.:** Bull Run Mountains Natural Area Preserve, Little Ridge Loop Trail at Catlett Crk., N38.82642° W077.70203°, 28 July 2008, A.V. Evans, flying/woods AM (1); Occoquan, VIII.1919, Wickham (1). **Rockingham Co.:** Rader Mountain, FR 597, 7 October 1997, M. Donahue (1). **Spotsylvania Co.:** Fredericksburg, 11 August 1897, E. A. Schwarz (1). **Virginia Beach (City):** Camp Pendleton Annex, vic. NW jct. S. Birdneck & Washington Rds., N36.81383° W075.97079°, Malaise trap, 22 July-19 August 2009, A. V. Evans (1). **Wise Co.:** Powell Mountain Karst Preserve, Cedar Ridge Malaise trap, ca. 1.3 km E Cracker Neck Church, N36.8538533° W082.6998265°, 29 July-20 August 2009, C. S. Hobson (1); same data except 20 August-21 September 2009 (1). (AVEC, GWMP, NMNH, VMNH, VPIC).

Little has been published on this species. Say (1835) frequently observed this species on the flowers of "a resinous plant common on the prairies of Missouri." Wenzel (1886) observed *S. petrophya* near Philadelphia during the summer, mostly in mid-July. Dirt encrusted adults, mostly females, were found emerging from the ground in the morning and crawling up the trunks of American Beech (*Fagus grandiflora*). They have also been found under bark or on trunks of trees (Blatchley, 1910).

In Virginia, *S. petrophya* is widespread (Fig. 7) and found in the Coastal Plain, Piedmont, Appalachian Plateau, and Ridge and Valley physiographic regions. Habitat at the Turkey Run Park collection site is successional Tulip-tree (*Liriodendron tulipifera*) forest with nearby mature stands of mesic mixed hardwood forest consisting of oaks (*Quercus* spp.), hickory (*Carya* spp.) and Sugar Maple (*Acer saccharum*). Evans observed and collected a single female flying next to a stream through a wooded area about 1000 h in July in the Bull Run Mountains Natural Area Preserve in Prince William County.

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Sandalus was conducted by Evans while he was employed as a field zoologist with the Virginia Department of Conservation, Division of Natural Heritage, Richmond, VA. Michael Kieffer (Bull Run Mountains Conservancy, The Plains, Virginia), the Cave Conservancy of the Virginias (Glen Allen, Virginia), and Taura Huxley (NAVFAC Atlantic, Norfolk, VA) provided access and additional logistical support for these surveys. Chris Hobson (Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA) selected and established the Malaise trap site in the Powell Mountain Karst Preserve that produced specimens of *Sandalus petrophya*. The National Park Service funded Evans' work on a beetle survey of the George Washington Memorial Parkway during 2010-2011. We also thank Anne Chazal (Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA) for generating the distribution maps. Kerry Katovich (University of Wisconsin-Whitewater, Whitewater, WI), Steve Roble (Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA), and Charles Staines (National Museum of Natural History, Washington, DC) suggested numerous corrections and comments that improved the accuracy and clarity of this paper.

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Annotated List of the Metallic Wood-boring Beetles (Insecta: Coleoptera: Buprestidae) of the George Washington Memorial Parkway, Fairfax County, Virginia

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ABSTRACT

Twenty-three species in nine genera of metallic wood-boring beetles (Coleoptera: Buprestidae) are documented from a national park site in Fairfax County, Virginia. *Paragrilus tenuis* (LeConte) and *Pachyschelus purpureus purpureus* (Say) are reported for the first time from Virginia.

Key words: Buprestidae, George Washington Memorial Parkway, National Park, new state record, *Pachyschelus purpureus*, *Paragrilus tenuis*, Virginia.

INTRODUCTION

As early as the mid-1800s North American entomologists were attracted to the family of beetles commonly known as the metallic wood-borers (Coleoptera: Buprestidae) (LeConte, 1860), undoubtedly due to the alluring nature of their glossy, metallic, iridescent colors and distinctive, often jewel-like, form. These hard-bodied beetles can be recognized by a combination of features including serrate antennae, down turned (hypognathous) head, dextro-sinistral metasternal suture, and basally connate abdominal sterna. Most adults feed on leaves, flowers and pollen, but species of *Agrilus* and *Chrysobothris* occasionally feed on the spores of fungi. Usually, eggs are inserted into cracks and crevices of wood, or for leaf-miners, deposited on the surface of the leaf and covered with a sticky substance that hardens into a protective cap. Larvae feed while burrowing through dead wood or cambium layers or while mining leaves and stems of herbaceous or woody plants (Bellamy & Nelson, 2002).

Compared to most other beetle families, the distribution of North American buprestids is fairly well known (Nelson, 1975; Nelson & Westcott, 1976; Bellamy, 1982; Nelson et al., 1982; Walters & Bellamy, 1982; Nelson, 1987; MacRae, 1990; Nelson & Nelson

et al., 1996; MacRae & Nelson, 2003; MacRae, 2006; Nelson et al., 2008). Despite the popularity of Buprestidae, recent surveys in a national park (George Washington Memorial Parkway) in northern Virginia, and examinations of local collections, have revealed two species previously unreported from the Commonwealth. We include those species, *Paragrilus tenuis* (LeConte) and *Pachyschelus purpureus purpureus* (Say), along with an annotated list of twenty-one other buprestids documented from the park.

STUDY SITES

Inventories were conducted on lands managed by the National Park Service as units of the George Washington Memorial Parkway (GWMP) at Great Falls Park, Turkey Run Park, Dyke Marsh Wildlife Refuge, and Little Hunting Creek, Fairfax County, Virginia, an area covering approximately 850 ha. Great Falls and Turkey Run parks lie in the Piedmont physiographic province while Dyke Marsh and Little Hunting Creek are situated on the Coastal Plain. Most of the study sites are dominated by maturing, second growth, deciduous woodlands, but more open, herbaceous dominated habitats can be found in narrow bands along the Potomac River and at Dyke Marsh. The vascular flora of the GWMP is diverse, with 1313 taxa recorded, 1020 from Great Falls Park alone (Steury et al., 2008; Steury, 2011).

METHODS

The number of buprestid species documented from the GWMP has grown since the first park records for this family, accounting for five species, were published based on surveys conducted on 23-25 June 2006 as part of the Potomac Gorge Bioblitz (Evans et al., 2008). Inventories conducted subsequent and prior to the Bioblitz survey have added buprestid specimens to the collections from GWMP, primarily as by-catch from studies targeting other arthropods that employed the following methods: 1) pan traps (blue, white, and yellow) to inventory bees at Great Falls Park in 2007 and 2008 (Steury et al., 2009); 2) Malaise traps (n = 6) operated at Great Falls and Turkey Run parks from 2006 through 2008 (Flint, 2011); 3) hand picking, pitfall, Lindgren funnel, and black light traps set at Great Falls Park, Turkey Run Park, Dyke Marsh Wildlife Refuge, and along Little Hunting Creek in 2010 and 2011; and 4) pit fall or Malaise traps operated at Dyke Marsh from 1998 through 2003 (Kjar & Barrows, 2004). To determine new Virginia records we reviewed published literature, the distribution database of Ted C. MacRae, and conducted searches of collections at the Virginia Museum of Natural History, Martinsville, Virginia (VMNH), National Museum of Natural History, Smithsonian Institution, Washington, DC (NMNH), George Washington Memorial Parkway (GWMP), and the private collections of Arthur V. Evans, Richmond, Virginia (AVEC) and Ted C. MacRae, Chesterfield, Missouri.

RESULTS AND DISCUSSION

Twenty-three taxa in nine genera were documented from the park. *Paragrilus tenuis* (LeConte) and *Pachyschelus purpureus purpureus* (Say) are reported for the first time from Virginia. The only methods which proved successful in capturing buprestids were Malaise traps (20 species), hand netting (6), and pan traps (3). Sixteen buprestid species were captured at Great Falls Park, 12 at Dyke Marsh, and six at Turkey Run Park. The Little Hunting Creek area, where only Lindgren funnel and pitfall traps were set, failed to capture any buprestids.

Paragrilus is represented by four species north of Mexico, with only *P. tenuis* (LeConte), known from the eastern United States (Hespenheide, 2002). Its maximum length is 5.5 mm and, as in all *Paragrilus*, the antennae are received in grooves. The host plants of larval and adult *P. tenuis* have been reported as *Hibiscus moscheutos* L. (Weiss & Dickerson, 1919; Hespenheide, 2002) including ssp. *lasiocarpos* (Cav.) O. J. Blanchard (Nelson, 1987; MacRae, 1991; MacRae, 2006). *Hibiscus laevis* All. is a reported host only in adults (MacRae, 2006). *Hibiscus moscheutos* ssp. *moscheutos* is a common plant in Dyke Marsh where *P. tenuis* was collected. The reported distribution of *P. tenuis* is Georgia (Franklin & Lund 1956), Delaware, Pennsylvania, Maryland, New Jersey, and New York (Nelson 1987), Florida, Illinois, Mississippi, and North Carolina (Nelson & MacRae 1990), Missouri (MacRae 1991) and the District of Columbia (Downie & Arnett, 1996). We add Virginia to the known distribution of *P. tenuis* based on the following specimens: **Arlington Co.:** 15 June 1903, Shoemaker (NMNH, 1). **Charles City Co.:** VCU Rice Center wetland, 1 May-17 June 2010, Evans (AVEC, **7**). **Fairfax Co.:** Black Pond reared on *Hibiscus*, 25 May 1919, Craighead (NMNH, 5); Black Pond, 19 June 1919, Middleton (NMNH, 1); Black Pond, 17 June 1920, Fisher (NMNH, 11); Great Falls, 16 June 1919, Middleton (NMNH, 1); Dyke Marsh, 24 June-19 July 1998, Barrows (GWMP, 2). **Nelson Co.:** 29 July 1910, Robinson (NMNH, 1).

The *Pachyschelus* fauna of America north of Mexico includes eight species and one additional subspecies (Hespenheide, 2003). North American

Pachyschelus rarely exceed 3 mm in length and have a large, triangular scutellum giving them an obovate periphery. *Pachyschelus purpureus* is the only eastern North American species with white pubescence on the elytra. The pubescence occurs in a diagonal or subtransverse line just before the apices. The elytra of the nominate subspecies are predominately dark blue and those of subspecies *P. p. uvaldei* Knull are reddish-purple. The larvae of *P. p. purpureus* are leaf miners of *Geranium* (Hespenheide, 2003). Two species, *Geranium carolinianum* L. and *G. maculatum* L., have been documented from the collection site at Great Falls Park, with *G. maculatum* being the more commonly observed species (Steury et al., 2008). MacRae (1991) found *P. p. purpureus* leaf mining *G. maculatum* in Missouri. The reported North American distribution of *P. purpureus* is Oklahoma (Nelson, 1987), Missouri (MacRae, 1991), Alberta, Ontario, Alabama, Illinois, Indiana, Iowa, New Jersey, New York, Ohio, and Texas (Downie & Arnett, 1996), and Arizona, Connecticut, District of Columbia, Illinois, Indiana, Iowa, Massachusetts, Michigan, New Mexico, North Carolina, Pennsylvania, Rhode Island, Tennessee, and Wisconsin (Hespenheide, 2003).

We add Virginia to the known distribution of *P. p. purpureus* based on the following specimens: **Arlington Co.:** Glencarlyn, 1 May 1910, Knab (NMNH, 4); Glencarlyn, 18 June 1912, Shoemaker (NMHN, 1); Glencarlyn, June 1925, Bridwell (NMNH, 1). **Fairfax Co.:** 25 June 1911, s.n. (NMNH, 2); 20 June 1912, s.n. (NMNH, 1); Great Falls Park, 1-20 May 2009, Steury (GWMP, 1).

LIST OF SPECIES

Nomenclature follows Nelson et al. (2008). Taxa are listed alphabetically. The number of specimens in the GWMP collection is given in parentheses followed by the collection site acronyms: Dyke Marsh Wildlife Preserve (DM), Great Falls Park (GF), and Turkey Run Park (TR). Methods of collection are given as hand netted (hn), Malaise trap (mt), or pan trap (pt). The early and late dates of collection are given (including the entire length of a trap set).

Acmaeodera pulchella (Herbst)–(1); GF; pt; 30 Jun

Acmaeodera tubulus (Fabricius)–(9); GF; pt; 9 Apr-23 May

Agrilus bilineatus (Weber)–(10); DM, GF; hn, mt; 21 May-13 Jul

Agrilus cephalicus LeConte –(2); DM; mt; 10-28 May

Agrilus lecontei lecontei Saunders–(3); DM, GF, TR; mt; 19 Jun-2 Jul

Agrilus obsoletoguttatus Gory–(8); DM, GF, TR; hn, mt; 19 Jun-21 Jul

Agrilus paracelti Knull–(2); GF; mt; 1 May-30 Jun

Agrilus sp. (*otiosus* group)–(1♀); TR; mt; 19-30 Jun

Agrilus ruficollis (Fabricius)–(2); GF; hn; 19-30 Jun

Agrilus subcinctus Gory–(1); DM; mt, 6-14 Jun

Anthaxia (*Haplanthaxia*) *viridifrons* Gory–(2); DM, TR; hn, mt; 20 Jun-2 Jul

Brachys aerosus Melsheimer–(1); GF; mt; 30 Jun-13 Jul

Buprestis (*Knulliobuprestis*) *rufipes* (Oliver)–(2); DM, TR; hn, mt; 24 Jun-8 Oct

Chrysobothris azurea LeConte–(2), GF; mt; 19-30 Jun

Chrysobothris sexsignata (Say)–(3); DM, GF; mt; 20 Jun-13 Jul

Chrysobothris shawnee Wellso & Manley–(2); DM, GF; mt; 6 Jun-26 Jul

Chrysobothris viridiceps Melsheimer–(2); DM, GF; mt; 14 Jun-26 Jul

Dicerca obscura (Fabricius)–(1); DM; mt; 17-28 May

Pachyschelus laevigatus (Say)–(4); GF; hn, pt, mt; 24 Jun-17 Jul

Pachyschelus purpureus purpureus (Say) –(1); GF; mt; 1-20 May

Paragrilus tenuis (LeConte)–(2); DM; mt; 24 Jun-19 Jul

Taphrocerus nicolayi Obenberger–(17); GF, TR; mt; 30 Jun-21 Nov

Taphrocerus schaefferi Nicolay–(1); GF; mt; 10-30 April

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Shorter Contributions

Banisteria, Number 39, pages 76-77

COOPER'S HAWK (*ACCIPITER COOPERII*) TAKES WOOD DUCK (*AIX SPONSA*): PATHOLOGY AND PROCESS OF AN EXCEPTIONAL PREDATION EVENT. — Well-documented interactions between predators and prey seldom include pathological examination of the kill, particularly when the species preyed upon is one very rarely taken by the predator. I document an instance in which I discovered a Cooper's Hawk (*Accipiter cooperii*), which usually feeds on medium-sized birds such as Mourning Doves (*Zenaida macroura*), with the carcass of a partially eaten adult female Wood Duck (*Aix sponsa*). My observations were made at 1245-1250 h on 25 March 2012 at a point 30 m WNW of the intersection of Brooke Road and Sentinel Ridge Lane (Google Earth coordinates 38°22′25.28″N, 77°20′14.82″W), 8.2 km SE of Stafford, Stafford County, Virginia. Brooke Road is a winding, two-lane, paved lane that exists mainly for residential access and ends at a local historical park at Aquia Landing at the juncture of Aquia Creek and the Potomac River. The day in question was an unpleasantly cool (ca. 11-13 C°), completely overcast Sunday when traffic would have been minimal. The habitat at the point of the observation is low, swampy deciduous forest with pools and streams and numerous old gnarled trees with broken branches ideally suited for providing cavities for nesting Wood Ducks.

My attention was drawn to a Cooper's Hawk at the bottom of a V-shaped concrete drainage ditch that was situated parallel to and about 5 m away from the edge of the road. I stopped at a point about 30 m distant where I had a clear view down the ditch with binoculars and noted that the hawk was large, mostly dark brown suffused with fuscous above, with blackish barring on the tail and so heavily barred with rufous below that the underparts appeared almost solid reddish, all indicating an adult female, the larger sex (lack of reddish shoulder patches and white bars in the tail rule out Red-shouldered Hawk *Buteo lineatus*). It remained stationary at the bottom of the ditch for several minutes amid a large accumulation of what seemed to be down. My proximity and the passing of several vehicles apparently caused the hawk to take flight, whereupon I walked to the point where it had been and found the carcass of a female Wood Duck and a large pile of its feathers, some of which had blown farther along the ditch. The carcass was well below normal body temperature but still warmer than the ambient temperature, the eyes were somewhat desiccated and rigor mortis had set in.

The hawk had evidently been at the task of eating for some time. The left side of the breast of the duck had been plucked and the skin and much of the pectoralis muscle down to the supracoracoideus had been eaten. The sternal ribs had been neatly pulled from their articulations with the sternum and were presumably eaten along with the costal musculature, exposing the viscera. A portion of the left lobe of the liver had been eaten, a bit of muscle had been picked away from around the left knee, and a small hole had been made at the juncture of the proventriculus with the gizzard. Before my arrival, it is unlikely that the hawk had left the carcass to feed young because Cooper's Hawks in Virginia are not known to begin laying before April and would usually not have young until May (Clapp, 1997).

The duck was moderately fat, was not molting, and contained a fully-formed shelled egg (unbroken) weighing 34.4 g. There were five unshelled ova ranging from 8 to 30 mm in diameter, as well as smaller undeveloped ova. The earliest egg dates for Wood Ducks in Virginia are in the first week of March (Clapp, 1997). The weight of the partially eaten carcass was 610 g. The weight of an amount of skin and muscle from the right side approximately equivalent to that removed by the hawk from the left weighed 46 g, for a total of 656 g, which would be a minimum considering reduction by desiccation and fluid loss. This value is very close to the average weight (667 g) reported for adult female Wood Ducks (Hepp & Bellrose, 1995). By contrast, the weight of female Cooper's Hawks ranges from 460 to 643 g (n = 109, spring and fall combined; Mueller et al., 1981).

Apart from the portion of the duck exposed during feeding, the only external signs of trauma consisted of a bloody spot at the base of the white throat patch and blood around the mouth. Upon skinning, the only signs of attack by the hawk were on the posterior portion of the head and the adjacent foreneck. There was a slight tear in the skin at the site of the blood on the throat and four puncture wounds as follows: about 1 cm below the left eye; on the left side of the neck dorsal to the white of the throat about 4 cm behind the eye; at the dorso-posterior margin of the left eye; and on the right side of the neck 3 cm behind the skull. This indicates that both feet were employed in holding the duck by the head and neck. There were small hematomas in the areas of the puncture marks but no significant internal bleeding and no blood in either the trachea or esophagous. It is possible that the feet of the hawk may have compressed

the trachea and major blood vessels in the neck initiating asphyxiation and/or strangulation but it seems unlikely that this would have lead to death except over a relatively long period of time. On further dissection, however, it was found that the thoracic cavity and lungs were filled with blood, possibly the result of a stress-related ruptured aorta.

There is no possibility that the hawk scavenged the duck after it had been struck by vehicular traffic on the road. There was absolutely no evidence of blunt-force trauma, no crushed skull nor any broken bones anywhere (except the sternal ribs removed by the hawk in the process of eating), and the duck contained an unbroken, shelled egg, which would have been unlikely to have survived an automobile strike intact.

Accounts of Wood Ducks seldom mention predation on adults, with the only avian predator mentioned by Hepp & Bellrose (1995) being the Great Horned Owl (*Bubo virginianus*). Although "teal and young of other ducks"are mentioned as food of Cooper's Hawks (Bent, 1937: 118), no further documentation was supplied. No ducks of any species were listed among prey items of Cooper's Hawk by Rosenfield & Bielefeldt (1993), although they do mention prey of even larger size such as Ring-necked Pheasant (*Phasianus colchicus*), females of which average 993 g with males being considerably heavier (Guidice & Ratti, 2001). A pheasant would most likely be attacked while on the ground, whereas the Wood Duck reported here was likely struck while in flight.

I did, however, find one account in New Mexico (Cartron et al., 2010: 189) in which one of the authors "once witnessed a female Cooper's Hawk dive at a Wood Duck (*Aix sponsa*) hen that had just taken flight. The two tumbled to the ground, and quite a struggle ensued. But the Cooper's Hawk might have been wary of human presence and did not continue the fight for long. She released her grip on the Wood Duck and flew off, while the duck struggled into nearby thickets. Later that day, while walking in the same vicinity, [the observer] flushed a female Cooper's Hawk off a dead female Wood Duck on the ground. The hawk had consumed quite a bit of breast meat, indicating that she had been feeding for a while. How soon she returned to finish off the duck after the initial attack is unknown." Thus, it is evident that Cooper's Hawks, one of the most rapacious predators of birds in North America and a notorious killer of domestic poultry (Bent, 1937), may prey on Wood Ducks anywhere that the ranges of the two species coincide, although this is evidently a rare and unusual event.

ACKNOWLEDGMENTS

I thank Gary R. Graves for helpful comments on the manuscript. The Wood Duck was prepared as a complete skeleton with spread wing and tail (USNM 623662) and associated egg cataloged separately in the collections of the National Museum of Natural History, Smithsonian Institution. I am grateful to Christina Gebhard and Brian Schmidt for labeling, cataloging, and other preparation assistance.

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STACHYOCNEMUS APICALIS IS REDISCOVERED IN VIRGINIA (HETEROPTERA: ALYDIDAE). — With a known range extending from Connecticut to Florida, west to California and Mexico, and north to Alberta (see map in Hoffman, 1992), the small, structurally distinctive *Stachyocnemus apicalis* (Dallas) is at once one of the most widely distributed and rarely collected species of Alydidae. The only record of its occurrence in Virginia is based on a specimen collected by G. W. Underhill at Chester (Chesterfield Co.) on 24 May 1920. Nonetheless, my treatment of these bugs (Hoffman, 1975) naively predicted that "Probably devoted collecting efforts will turn up *apicalis* at other places in eastern Virginia."

Thirty-six years later, and despite a lot of collecting in eastern Virginia since 1989, the species had still not turned up, and I had given up any hope of ever seeing new instate material. But the law of serendipitous discovery is still in effect, and in mid-summer of 2011, I collected a specimen of this elusive bug in Martinsville. The residential enclave where I live has a small swimming pool to which I sometimes resort, and from which various drowned insects and spiders are salvaged. During the early summer of 2011 I had not indulged in either activity, but the ambient temperature of 98° F /36° C on 21 July induced an impulse to enjoy a cooling swim. As usual, the occasion was taken to harvest floating insects of possible interest for the VMNH collection, and among the selection was a small dark bug that I first thought was a rhopalid, but as it dried that guess had to be revised to "unknown small alydid." The actual identity only emerged the next morning when access to a microscope revealed the striking habitus of *S. apicalis.*

The collection site, in a suburban cluster of townhouses and small residences, is surrounded by a thin fringe of second growth pines and broadleaf trees. There is nowhere in the vicinity anything like the dry, sandpit biotope said to be favored by the species (Vestal, 1913; Blatchley, 1926).

Aside from confirming the continued existence of the species in Virginia, the specimen (deposited in the VMNH collection) represents an extension of its known lowland range about 138 miles/230 km westward across the Piedmont.

Stachyocnemus apicalis is easily distinguished from other members of its family in Virginia by a small acute projection on the posterior edge of the pronotum, two rows of spinules on the metatibiae, and especially the profuse black setation of the body that imparts a bristly appearance. An excellent photograph of the species is available at http://bugguide.net/node/view/471616/bgpage.

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Miscellanea

Reports

1. President's Report

Sadly, we have learned of the death of Dr. Richard Hoffman on 10 June 2012. Dr. Hoffman was a co-founder of the Virginia Natural History Society in 1992. He was a strong supporter of the Society in many ways. He was co-editor of *Banisteria* from 1992 until 1999 and then Associate editor until his death. Richard served as Honorary Councilor from 2001-2012. By my count (through number 38), Richard published 75 articles in *Banisteria*. These include 51 on insects, 10 on spiders, five on centipeds, three on mollusks, two on millipeds, and one on frogs. Additionally, he wrote three book reviews and was a manuscript reviewer. In only eight issues of *Banisteria* was he not a contributor. This broad spectrum of topics illustrates his interests and expertise. Yet many in the world knew him only as the consummate milliped taxonomist. We knew him as a student of the natural history of Virginia. He will be missed.

The Virginia Natural History Society (VNHS) has been invited to participate in a joint meeting with the Virginia Academy of Science (VAS) at its 91st Annual Meeting at Virginia Tech in Blacksburg, VA. That meeting will be held in the latter part of May 2013. Members of the VNHS will not need to be a member of the VAS in order to present a paper. However, presenters must register to attend the meeting. Both oral presentations and poster presentations are welcome. Any one of the many VAS sections may be appropriate in which to present your research. This is a one time trial and a change of policy for the VAS. Start thinking about what natural history research you could present. Specific information about dates, deadlines, and registration will be sent to all members as it becomes available.

Respectfully submitted
Ralph Eckerlin, President
Virginia Natural History Society

2. Minutes of the Executive Committee of the Virginia Natural History Society Meeting of December 3, 2011

The 2011 meeting of the Executive Committee of the Virginia Natural History Society was called to order by President Ralph Eckerlin at 1:00 PM on December 3rd, in Settle Hall at Hampden-Sydney College, Hampden-Sydney, Virginia. In attendance were Bill Shear, Richard Hoffman, Judy Winston, Ralph Eckerlin, Tom McAvoy, Steve Roble, Michael Kosztarab, Lisa Williams, Richard Groover, and Mike Lachance.

The minutes of the 2010 meeting and the report of the Secretary-Treasurer were approved unanimously. Membership (as of December 2011) presently stands at 117 (including 19 institutional members), and the treasury contains $9,360.66. The Secretary-Treasurer's full report, updated to June 2012, is appended to these minutes.

President Eckerlin relayed a report from webmaster John White. The society's webpage is currently carried without charge on the server of the Conservation Management Institute in Blacksburg. When the institute moves its website, the VNHS page loses its URL and all links are broken. This has happened twice in the past. John White now expects the CMI site to be stable for the foreseeable future, and recommends not moving to a commercial host. The consensus of the committee was that his recommendation should be accepted (upon further consideration, a decision was made several weeks later to move the VNHS website to a commercial hosting service).

Steve Roble presented the editor's report. The current issue of *Banisteria* (No. 37, for Spring 2011) was mailed November 22nd, 2011; 130 copies were printed. Steve had some questions for the group. Should the waiver of page charges for a multi-author article be restricted to such articles where the member is the senior author? After some discussion, it was agreed that this should be the policy and that it should be referenced in the next issue. The group also agreed to raise the fee for color illustrations from $50/page to $75/page. Steve stated that the next issue (No. 38) will be at the printers' before Christmas and should be ready to mail before February 1st. He also passed out a prospectus for the next four issues. There followed discussion of the proposed contents of those issues.

Steve had consulted Joe Mitchell regarding the publication of papers from the society's 2009 symposium entitled "Historical Explorations into Virginia's Natural History." The idea of having a book published is evidently dead. Only two authors have submitted manuscripts. It was concluded that those two papers should be published in *Bansiteria* if they are suitable. The fate of the other papers depends on their authors; should they submit them to *Banisteria* they will be considered for publication there.

There followed a brief discussion of how to get *Banisteria* into various databases and indexed by search engines.

Ralph Eckerlin presented the president's report. He drew attention to the many suggestions made in 2010 to increase membership and noted that nothing had been done on any of these. A proposal to exchange journals with *Senckenbergiana biologia* was declined because we have no repository in which to place exchanged journals. At the May meeting of the Virginia Academy of Science, the Biodiversity and Natural History section had 14 oral reports and 5 posters, a considerable increase over previous years.

There followed a discussion of the need for a new recruitment brochure. Steve Roble and Bill Shear were charged with investigating the costs for a full-color, glossy, 3-fold publication.

Under old business, recruitment of new members was discussed and many of the ideas proposed in 2010 were brought up again, but no action was taken.

Under new business, Ralph noted that the Society has not been following its own bylaws. He distributed printed copies of the bylaws with some suggested changes, and asked members of the committee to examine them over the next year and suggest corrections and changes of their own.

The meeting was adjourned at 3:15 PM.

Respectfully submitted,
William A. Shear, Secretary/Treasurer

3. Secretary-Treasurer's Report, June 2012

As of June 30, 2012, the society has 107 members, including 17 institutions. This represents a decrease in membership from December 2011 (117 members, 19 institutions). In December 2010, we had 105 members, including 17 institutions. Except for 2011, membership has declined over the past six years from the most recent high point in 2004, when we enrolled 165 members, including 22 institutions.

Our current bank balance is $10,090.37, up $729.71 from one year ago.

Respectfully submitted,
William A. Shear, Secretary/Treasurer

4. Webmaster's Report

VNHS website traffic from 18 December 2011 to 1 June 2012 is summarized in the following table:

Summary by Month

Month	Daily Avg				Monthly Totals					
	Hits	Files	Pages	Visits	Sites	KBytes	Visits	Pages	Files	Hits
Jun 2012	21	11	6	6	10	1001	6	6	11	21
May 2012	117	80	20	13	499	662690	429	623	2504	3653
Apr 2012	172	110	21	14	548	1018858	423	640	3329	5172
Mar 2012	94	68	13	10	380	302699	329	418	2134	2934
Feb 2012	121	75	14	10	375	320517	312	434	2183	3536
Jan 2012	115	65	12	7	338	239051	240	373	2016	3573
Dec 2011	98	67	22	7	134	76993	103	314	948	1377
Totals						**2621808**	**1842**	**2808**	**13125**	**20266**

On or about 18 December 2011, the Virginia Natural History Society's website was moved to a commercial hosting company. The new url for the website is: http://virginianaturalhistorysociety.com. The shorter url http://va-nhs.org will also work.

Respectfully submitted,
John White, Webmaster

5. Editor's Report

This 80-page issue of *Banisteria* is one of the largest in the 20-year history of the journal. I anticipate that the next issue will be comparable in size. My thanks to associate editor Joe Mitchell for soliciting peer reviews of the *Nicrophorus* paper.

Once again, I find that I must thank founding co-editor and recent associate editor Richard Hoffman one last time for his frequent advice and encouragement related to this journal. I was honored when he asked me to assume his role as co-editor of *Banisteria* in 2000 and have sought his advice related to this journal on many occasions during the past dozen years. He was not only the most prolific contributor of manuscripts to *Banisteria*, but also the most frequent peer reviewer (despite his general disdain for the peer review process), owing to both his great breadth of knowledge and general wisdom. Dr. Hoffman's recent passing is a big loss to the scientific community in general, to the study of natural history in Virginia in particular, and to the continued success of this regional journal. An obituary will appear in the next issue of *Banisteria*, along with some of Dr. Hoffman's first and last writings. He was still working six days per week at the time of his death at the age of 84 and had more than 50 unfinished projects or manuscripts in progress. I will try to help complete as many of those pertaining to Virginia as is possible.

Respectfully submitted,
Steve Roble, Editor, *Banisteria*

Virginia Natural History Society

http://virginianaturalhistorysociety.com/

General Information

The Virginia Natural History Society (VNHS) was formed in 1992 to bring together persons interested in the natural history of the Commonwealth of Virginia. The VNHS defines natural history in a broad sense, from the study of plants, animals, and other organisms to the geology and ecology of the state, to the natural history of the native people who inhabit it. The goals of the VNHS are to promote research on the natural history of Virginia, educate the citizens of the Commonwealth on natural history topics, and to encourage the conservation of natural resources.

Dissemination of natural history information occurs through publication of the journal *Banisteria*, named for John Banister (1650-1692) who was the first university-trained naturalist to work in Virginia. The first issue was published in 1992, and the journal is published twice per year in spring and fall. Articles cover a wide array of subjects, and prospective authors are encouraged to submit manuscripts on any aspect of natural history in Virginia; papers may pertain to Virginia or regional archaeology, anthropology, botany, ecology, zoology, paleontology, geology, geography, or climatology. Book reviews, biographies, obituaries, and historical accounts of relevance to natural history in Virginia also are welcomed. Manuscripts are peer-reviewed for suitability and edited for inclusion in the journal.

Page charges ($20/page) are waived if the sole or first author is a VNHS member. All authors must pay $75/page if they desire color printing of figures. The society's website contains detailed instructions for authors and the titles, abstracts or full PDF versions of articles from past *Banisteria* issues.

Memberships

The VNHS is open to anyone with an interest in natural history and welcomes participation by all members in society activities and efforts to promote education and conservation. Membership includes a subscription to *Banisteria* and invitations to periodic symposia and field events. Annual dues for members are $20 (per calendar year); library subscriptions are $40 per year. Checks should be sent to the Secretary/Treasurer, who also has back issues of *Banisteria* available at $10.00 each (except Nos. 1-6 are $5.00 and No. 13 is $18.00). The VNHS is a tax-exempt, nonprofit, society under Section 501(C)3 of the IRS. We welcome donations to support our mission in Virginia.

Virginia Natural History Society

Application for Membership

Name ________________________________

Address________________________________

____

____

Zip Code _____________________________

Phone ________________________________

Email ________________________________

Area(s) of Interest ________________________

ANNUAL DUES AND SUBSCRIPTIONS TO *BANISTERIA*

(memberships and subscriptions are by calendar year; subscribers/members outside the United States should add $3.00 for additional postage)

- ☐ $500.00 Life (not annual)
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- ☐ $20.00 Regular
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The special student rate is applicable only when accompanied by the following certification signed by a faculty advisor.

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Date_________________________________

Make checks or money orders payable to:
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Send membership form and dues to:
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